THE OHIO JOURNAL OF SCIENCE

Vol. XXIII MARCH–APRIL, 1923 No. 2

STUDIES OF THE BIOLOGY OF FRESHWATER MUSSELS.

II. THE NATURE AND DEGREE OF RESPONSE TO CERTAIN PHYSICAL AND CHEMICAL STIMULI.*

WILLIAM RAY ALLEN

Department of Biology, Municipal University of Akron, Ohio.

CONTENTS.

1. Introduction..... 57
2. The sensory epithelia..... 58
3. Physical stimuli..... 59
   a. Mechanical..... 59
   b. Thigmotropic and rheotropic reactions..... 63
   c. Light and phototropism..... 64
   d. Hydrostatic pressure..... 72
   e. Equilibrium, shell weight, and posture..... 73
   f. Résumé..... 75
4. Chemical stimuli..... 76
5. Tonus of the siphons..... 79
6. Accessory siphons..... 79
7. Résumé..... 80
8. Concluding remarks on the nervous system..... 80

1. INTRODUCTION.

During the progress of studies upon the nature of the food of the Unionidæ (Allen, '14) it became important to know what power of food selection is exercised. Such selection involves the possession of sensory nerve endings in the epithelia. The writer has attempted to demonstrate the nerve endings in the various epithelia by two methods—histological and experimental. Histological methods have so far been almost wholly unsuccessful, insofar as revealing the qualitative arrangement of the several types of nerve endings

*Contribution from the Zoological Laboratory of Indiana University, No. 192.

is concerned. The experimental method as applied to the study of the control of ingestion has been much more profitable (Allen '21, 1). The present paper embodies the observations made during the same time upon the effects of stimulation of the several regions of the mussel epithelium which are normally exposed.

The mussels used in this work were the species commonest in Winona Lake, Indiana, and in the White River at Gosport and Shoals, Indiana. From the lake were obtained *Anodonta grandis* and *Lampsilis luteolus;* from White River, *Quadrula heros, Q. pustulosa, Q. lachrymosa, Q. undulata, Unio crassidens, U. gibbosus, Lampsilis ligamentinus, L. alatus, Plagiola elegans,* and others.

The methods of study will be outlined under each respective heading in the body of the paper. For convenience they will be grouped first as to their chemical or physical nature.

2. The Sensory Epithelia.

The exposed soft parts of an extended mussel are the foot, mantle edge, and siphons. That they bear more highly sensory epithelia than those enclosed within the shell is easily shown by experiment.

The *foot* is of course largely muscular. Numerous blood sinuses lie beneath its epithelium and cover the muscular portion. The sinuses diminish toward the ventral margin of the foot, and where they occur the foot is most sensitive to tactile stimuli.

With the gaping of the shell to allow for the protraction of the foot, open spaces anterior and posterior to the foot would be formed were it not that the *mantle* is adapted for closing the apertures. It is inserted into the shell parallel to its margin, in the pallial line. The edge of the mantle distad to this line is muscular, and the muscular zone of the right and left mantle lobes respectively are projected beyond the edge of the valves until they meet in the median line. The deep-burrowing sedentary *Lampsilis anodontoides* produces furthermore a considerable overgrowth of periostracum which answers the same purpose when the mantle is retracted.

The *siphons* are by no means so well developed nor so deserving of the name as in some of their marine relatives.

Compared with the general mantle margin, they are more muscular, slightly more protractile, and possess a greater innervation. In many marine species the mantle edges are sufficiently united to constitute closed tubes. But the freshwater forms (Sphaeriidæ excepted) have the mantle edges united only at one point—i. e., their junction with the suprabranchial septum, thus separating the dorsal and ventral siphons.

The siphons differ from the subjacent general mantle edge in the possession of papillæ. The dorsal siphon tends to have a single row of small papillæ, while the ventral has two or three rows of much larger ones. By means of these the sensory surface is much increased.

3. Physical Stimuli.

Many details of the following experiments will be omitted, for the sake of summarizing numerous experiments in few pages, and to secure continuity and clearness.

(a) *Mechanical, or Tactual, Stimuli.*

The effects of contact of the siphons, mantle edge, and foot with objects of various character were noted. A dissecting needle, camel's hair brush, and wooden spatula were used for their varying size, hardness and sharpness. They were brought into contact with a greater or less surface, with greater or less impact, and for greater or less lengths of time.

(1) *The Foot.*

Upon the muscular portion of the foot a needle-point produces an unappreciable local effect, simply a depression of the area surrounding the point touched. At times of low activity the foot may even be pricked without a very considerable retraction. If a long time (30 seconds or more) elapses between stimuli, the same point may be touched repeatedly without additional result. However, when the same point or adjacent points are repeatedly stimulated at rapid intervals, the foot may be withdrawn to a considerable extent. This again depends upon temperature, oxygen supply, etc. Those individuals which are well fed, which have been living in well ærated water, and in water of 18° to 25° C. react more readily to all stimuli than do those under other con-

ditions. Extremely unfavorable state of the water may result in a mussel's tendency to lie prone with the foot extended and mantle gaping.

The camel's hair brush is incapable of initiating more than local movements. The spatula produces a wider response than does the needle point. The larger, then, the surface stimulated the more profound is the response. Repeatedly touching with the spatula soon causes the foot to retract, sometimes entirely within the shell.

The response to two needle points simultaneously is greater when some distance apart, but not so great as that produced by the spatula.

(2) *The Mantle Edge.*

The mantle margin is more sensitive than the foot. A gradation from the middle, both forward and backward, is perceptible. That is the poorest innervation occurs near the middle of the mantle in the portion near the foot. Toward the two extremities it becomes more sensitive.

The camel's hair brush, needle, etc. produce a marked response when touched to the mantle edge, and the spatula still greater effect. Not so many repetitions of a stimulus or so vigorous contact is required as upon the foot. The stimulus of one contact is held over for a longer time than on the foot, while a second or third increases the effect. Repeated or vigorous stimulation causes a discharge of water from the mantle chamber by adduction of the shell, and when kept up may incite burrowing.

(3) *The Siphons.*

A minimum of stimulation produces a maximum of response when applied to the siphons. The camel's hair brush is as effective as the needle point. Contact with a single papilla results usually in the retraction of the papilla alone. A repetition at intervals may cause the adjacent region of the siphon to draw back. Only a considerable impact upon a single papilla can cause the siphons to close or cause a discharge of water from the mantle chamber. Of course in this case the thrust is transmitted through the papilla to the surrounding mantle, and other nerve endings are affected.

The result is greatly amplified when two or three papillæ are stimulated together or in close succession. The nearby portion of the siphon is drawn back sharply, and repetition may cause the discharge of water. Often also there is a readjustment of posture, and more or less burrowing may follow.

If the contact is sufficiently vigorous upon either ventral or dorsal siphon, both close. Yet a slighter pressure upon the ventral siphon is required than upon the dorsal to cause the closure of both. This is as might be expected. The ventral opening is the larger and it receives the incurrent stream. For both reasons it should be well guarded. Mussels are often seen to hold the tips of the opposing rows of papillæ together in the median line, thus testing the entering water more thoroughly than when the siphons are wide open. There is less likelihood of attack through the excurrent opening against the streaming water.

We have reason to conclude that there exist no local reflexes by which the muscles of one siphon are caused to react to a stimulus from receptors of the other. Such stimuli probably must pass through the visceral ganglion, for it innervates the two siphons through distinct tracts by way of the pallial nerve.

Furthermore, it is easily seen that the two lips of either siphon are without a nerve commissure connecting right with left. When a sufficiently slight tactual or chemical stimulus is applied to one side of a siphon, that side alone gives a response. If the stimulus is increased in magnitude it reaches the visceral ganglion and is transmitted also to the other side of the siphon. This involves of course the pallial nerves of both mantles, both hemispheres of the visceral ganglion, and their commissure. Local reflexes govern only the muscles of the respective halves of either siphon. The fusion of the two siphons with the supra-branchial septum and with each other is very superficial, and has not affected the nerve supply. The siphons are not units in a complete morphological sense, but only somewhat differentiated areas of the mantle edge, left and right.

The two siphons are, then, differentiated primarily for the admittance and discharge of water. In the exercise of these functions they have acquired a further specialization—the

ventral in a sensory direction, the dorsal in a motor, for the control of the flow of water. The ventral is often observed to stand open, while the dorsal is to a greater or less extent closed. Surprisingly the sense organs of the ventral siphon exercise a more profound and lasting effect upon the dorsal siphon than upon the muscles of the ventral itself; and as a corollary a more profound effect than is produced by the sense organs of the dorsal itself. The following sequence of reactions has been secured many times:

1. Ventral strongly stimulated. Both siphons close vigorously. Both reopen together.

2. Stimulus repeated soon. Both siphons close. Ventral reopens, then dorsal.

3. Stimulus again repeated. Dorsal siphon closes. Ventral not entirely closed, and reopens at once.

Thenceforward there is a greater effect upon the dorsal than upon the ventral. The former has the manner of opening cautiously, tentatively. If the dorsal siphon is similarly irritated, there comes at last to be some response from the ventral, and a more local, temporary one from the dorsal itself.

The parts of the ventral siphon were shown not to be equally sensitive. The inner margin, next the lumen, is most responsive. The papillæ of the inner circle are longer and larger than the outer ones. The latter may sometimes be touched with only a local, temporary effect, while an equal contact with the inner or marginal papillæ results in a general and vigorous response. This should be expected since the marginal papillæ are nearest the inflowing water. The dorsal does not show such unequal distribution of the tactile organs.

In studying the method of burrowing in *Quadrula undulata* it was observed that the animal employed the papillæ to gauge its depth in the substratum. When pulling itself further into the sand, the mantle and siphons were withdrawn more or less out of the way and the valves as closely appressed as possible. Alternating with this movement the siphons were extended and the papillæ spread out, some of them upon the sand. Without doubt the relation of the papillæ to the substratum, and to the free water above, provide the necessary orientation of the burrowing reflexes.

The still more deeply burrowing forms, such as *Plagiola elegans*, withdraw wholly into the sand. A little funnel-shaped crater affords communication with the water above. The papillæ of the siphons are spread out radially upon the sand at the bottom of this crater. They not only aid in holding back the sand, but also warn the animal when it accumulates. The response is an adduction of the shell, perhaps repeated, which sweeps out with a jet of water the excess sand and restores its proper equilibrium.

(b) *Thigmotropism and Rheotropism.*

At this point mention should be made of the mechanical effects of obstructions in the substratum and the thrust of the current.

The movements of a mussel, by alternate distension and retraction of the foot and the flow of blood in the serous spaces, suggest amoeboid locomotion. Observation has shown also that there is no little resemblance to the thigmotropic reactions of *Amoeba* when obstructions are met with. Under conditions in which gravity and current may be disregarded it is learned that a mussel, diverted from its course by a stone or bit of wood, does not revert to the old course, but continues in the new.

This avoiding reaction is sometimes the result of inability to draw the shell past the barrier, and sometimes can be explained as an unequal tactual stimulation of the surfaces of the burrowing foot. As soon as equilibrium of friction is restored the animal proceeds again, in a new straight line.

In running water, if not of too great velocity, mussels often travel in a direct line transversely or obliquely to the current. When turned aside they often revert to the former course as soon as an obstruction is passed. The angle which their course makes with the current seems somewhat dependent upon the stream velocity. It is difficult to determine whether the orientation to the current is due to pressure upon the shell or to friction upon the siphon region.

After checking the movements of many individuals in streams it seems very probable that rheotropic reactions may account in part for the grouping of mussels in shoals, as well as for their orientation upon the shoals.

A state of approximate equilibrium in the substratum is preferred in streams. Where there is too great current eddies tend to develop around the shells of the more emergent species, washing the sand away and loosening their hold.

The importance of the above factors in local distribution has been discussed in the third paper of this series (Allen, '21, 2).

(c) *Light and Phototropic Behavior.*

The siphon not only has a better innervation, but is also more deeply pigmented than any other part of the mantle. This at once suggests light reception as one of its functions. Such differentiation of mantle finds its greatest expression, of course, in the more or less complex eyes of the Arcidæ and Pectinidæ. Hecht ('21) has defined the physiological aspects of photoreception in *Mya arenaria* and *Ciona intestinalis*.

(1) *Light Intensity.*

Three sets of experiments were carried out simultaneously in bright sunlight, subdued sunlight, and artificial light respectively. The animals were placed either in tubs or aquaria in which water was kept level by siphons, and ærated by dripping tap water. A sufficient depth of clean sand was used to allow entire freedom of movement. The experimental animals were periodically re-oriented with respect to the sources of light and their new positions and tracks noted—usually once each day. In the first experiment aquaria were used, at a south window. In the second the tubs stood just far enough from a south window to be out of direct light. In the third a 40-watt lamp was lowered into the center of a tub by means of an anchored museum jar of small diameter.

Quadrula heros was most useful in these experiments, due to its more frequent and more prompt response. This response is in part owing, no doubt, to its habit of turning and resting upon one side. Thus when originally placed erect on the sand it has this additional stimulus to incite movement. The species has an exceptionally heavy shell. When standing erect, hinge upward, it is in rather unstable equilibrium and tends through sheer weight to turn upon one side or the other.

It might be suspected that the results were due to the animals' seeking their reclining posture. That the stimulus to turn is not wholly due to this factor, but that light also

initiates movement is shown in the first experiment by the fact that the response is very much less on cloudy days, and that they did not follow the law of chance in the direction of movement.

Experiment 1. Direct Sunlight.

Single *Quadrula heros* were set in the center of an aquarium upon clean sand, beneath three or four inches of water, after previously allowing them to become adjusted to that depth. They were placed at a south window in direct sunlight throughout the day. They were put into an erect, unnatural posture, like that of *Lampsilis* or *Anodonta*. The siphons were turned toward the south.

The following table is a check upon the several successive occupants of an aquarium for three weeks. Possibly on account of shell weight, none failed to burrow after each forced change of posture, although some time always elapsed during which they remained motionless.

Date	Amount of turning of siphons in degrees from south	Remarks
May 8	90	
" 9	180	
" 10	45	
" 10	45	Cloudy.
" 13	180	Changed in morning; siphons turned eastward.
" 15	00	Very warm, partly cloudy.
" 16	00	Very warm, partly cloudy.
" 17	00	Very warm, partly cloudy.
" 19	90	Change in morning; siphons turned eastward.
" 20	90	
" 21	90	
" 23	90	
" 25	90	
" 27	00	
" 28	30	Eastward; cloudy forenoon.
" 29	90	

Total avoiding light.....11
Total turning toward light..... 0
Failure to respond to light..... 4

After recording each observation the experimental animal was set back to its original position, or another of the same species substituted. The reactions of May 15–17 were probably vitiated by the unusually high temperatures, although the water was changed daily.

The large number of quarter turns is significant. It is especially so since the animals usually turned clockwise, and were found with the siphons pointing westward. This is easily explained as an avoidance of the forenoon sun. Each experiment began in the evening, too late for the same day's sun to be effective. During the night the animal was becoming adjusted to its new position, and remained inactive. Not much movement took place until the following morning. Consequently the usual turning to the east with the siphons to the west during the forenoon accomplished as great avoidance of the sun as possible. During this rotation and following there was also a lateral burrowing movement which resulted in the animal's lying on the left valve, its foot parallel to the surface, and hinge turning northward. In this species the siphon is never extended far beyond the shell, and is usually wholly within the shelter of the valves. In this position they received the maximum amount of shade in the experimental animals.

In order to demonstrate that there is no preference for lying on the left valve, a series of similar experiments were made in the dark. The response was much less prompt in darkness. Fifteen finally assumed a position on the left side and sixteen on the right.

The degree of torsion is seen to be much reduced by cloudy weather. The above expression in degrees is of course approximate, for with the accompanying lateral movement exact measurement is difficult. Nor is it important.

Experiment 2. Subdued Sunlight.

In each of two tubs placed in indirect sunlight near the south windows six *Quadrula heros* were stationed. The windows of the room were such that the brightest light came into the tubs from the southwest, the least light from the dark southeast corner. There was considerable reflected light from the northeast. From still greater illumination at the west and northwest the light shaded off toward the east and northeast.

Running tap water kept the animals in vigorous condition. They were checked up and reset at frequent intervals. Those in "tub 1" were placed with the siphons toward the maximum light of the southwest, those of "tub 2" the reverse, with the

siphons pointing away from the maximum light, but not toward the minimum of the southeast. The following table indicates the reactions over a short period, though the experiment was kept up with modifications from January to the end of May.

Date	Tub 1			Tub 2		
	Remain toward light (Positive)	Turn to south (Negative)	Turn to north (Negative)	Remain toward light (Less Positive)	Turn to south (Negative)	Turn to north (Most Positive)
April 11.....	1	3	2	1	5	0
" 17.....	0	4	2	4	2	0
" 23.....	1	5	0	3	2	1
" 26.....	3	2	1	2	3	1
" 29.....	2	4	0	1	5	0
May 2.....	3	3	0	2	3	1
" 7.....	4	2	0	1	4	1
Totals.....	14	23	5	14	24	4
Another experiment using more intense light	4			13		

Total remaining toward light of greatest intensity, but not direct..... 4
Total remaining toward light of second order of intensity.....14
Total remaining toward light of third order of intensity.....27
Total reacting positively to light..... 4
Total reacting negatively to light.....52
Of the last total, turning to north from southwest..... 5
Of the last total, turning to south (darkest corner).....47

During the winter months the reactions were very slow and much less definite than in spring, though qualitatively similar. While it appears probable that there is a sort of hibernation, or seasonal rhythm in metabolism, aside from the effects of the immediate physical surroundings, yet there is no doubt that temperature is largely responsible for the increased activity of April and May.

From the above table it will be seen that nearly every day's record shows the directive agency of light. Usually a greater number of *Quadrula* reacted negatively to light than the number which failed to move at all. A still smaller number turned toward light of greatest intensity. It will be noted

that the reaction time was much greater in subdued sunlight than in direct. Given more time the above predominance of negative reactions would probably have been greater. Not only is it significant that there was an avoidance of southwest light, but that nearly all such cases turned the siphons toward the darkest corner of the room—the southeast—and few to the somewhat greater light of the north. Of course those which turned from the east to the north were reacting positively, while those which turned from the west to the north were changing the siphons into light of less intensity. The supplementary experiment at the end of the above table was an attempt to ascertain the result of using light of an intensity intermediate between Experiments 1 and 2. Equal numbers were used in tubs 1 and 2. In the former only four remained exposed to the greater light intensity, while thirteen remained passively siphoning toward the northeast in the second tub. In the totals it may seem inconsistent that the same number (fourteen) should have remained facing either direction. This is explained by the fact that the shock of handling or inertia is with difficulty overcome at first. Of more significance is the undoubted subsequent orientation with respect to light. The original inertia is seen to be overcome most rapidly by light of the greatest intensities.

In order to make certain that *Quadrulæ* do not have a preference for lying on the right or left side, a part of the experiment was repeated in darkness. The results were: Remaining erect, 13; on right side, 13; left side, 14. None were ever observed to change from one side to the other, either after assuming their position voluntarily, or after having been placed arbitrarily. Large numbers of observations verify this point. It is certain that no other element than light is responsible for influencing the direction of movement in the above experiments.

Experiment 3. Artificial Light.

In the tub kept in darkness and illuminated by a 40-watt lamp eight mussels of as many species were kept and checked from April 25 to May 27.

During the progress of the experiment the mussels were placed variously, having the siphons toward the light, away from it, and at various distances from it of one inch up to about eight inches. They were observed and reoriented twenty

times in the thirty-two days. Being 45° apart in the tub there was room for each to move without interference. There being twenty records for each individual, we have a total of 160 records. The total number actually changing posture was 61 out of the possible 160. There remain 99 negative results, a ratio of about three to two more or less positive results. The following species participated. The number of times each moved is indicated. *Lampsilis alatus*, 1; *L. ligamentinus*, 18; *Quadrula lachrymosa*, 0; *Q. pustulosa*, 1; *Q. heros*, 9; *Unio crassidens*, 14; *U. gibbosus*, 10; *Plagiola elegans*, 8. Average 7.6 out of a possible 20.

The above record is not significant, as an analysis of the behavior of the respective species, perhaps, on account of the small number used. But we do have a fair test of the average reaction in light of low intensity. The fact that *Quadrula heros* only changed position 9 times out of 20; 56 times out of 84 in Experiment 2; and 11 times out of 15 in Experiment 1, show a responsiveness to light that is in the inverse ratio of its intensity.

Temperature may be in part responsible. It varied between 12° C. and 16° C., averaging about 14° C. in the third experiment. In the second it averaged about 16° C. and ranged between 13° C. and 17.5° C. In the first experiment temperatures were still a little higher, but on the warmest days, which were also very cloudy, there was little response to be seen. Thus light was shown to be more pertinent than temperature.

Although only 61 out of 160 moved at all in this series of observations, yet only 11 of the 61 turned either toward or away from the light. The remaining 50 burrowed directly downward without a reorientation. Light evidently had little to do with these movements. Even when placed nearly in contact with the source of light there was not a perceptibly greater turning away from it than when separated by the radius of the tub. When tried four days in darkness 12 moved and 20 failed to do so, a not very different ratio. The above-mentioned reactions of *Quadrula heros* gave 13 out of 40 failing to burrow in darkness.

There are other evidences (Allen, '21, 2) that the optimum conditions for mussel life include a moderate amount of light, rather than extreme amounts. Light itself has little importance in the life of the organism—its significance lies in the accompanying complex of conditions.

(2) *Responses of the Siphons to Rapid Light Changes.*

When the mussel has been siphoning undisturbed the siphons respond to changes in light intensity. The magnitude of the response is more or less proportionate to the change in light. (See also Hecht, '21). If an object is interposed between the sun and the siphons, changing them from a condition of maximum illumination to deep shadow, there occurs a very prompt and complete closing of the siphons. A considerable time is then necessary to accustom the siphons to the lower light intensity. They slowly and tentatively reopen in the shadow. If the shadow is withdrawn, the direct sunlight again causes a closure, and a slow renewal of siphoning again takes place. By rapid and repeated changes between sunlight and shadow the siphons are first caused to close, then to draw into the shell, and finally comes an adduction of the valves and spurting of water from the siphons. Then normal siphoning is renewed. This reaction may be produced several times in succession. Usually a burrowing movement, or at least a change of posture, takes place.

The same reactions may be gotten in indirect sunlight, especially at a north window, or wherever most of the light comes from a single direction. At noon on bright days the response at a north window is not of much less magnitude than in direct sunlight. After four o'clock the reactions diminish in magnitude and reach the vanishing point before twilight. Very faint shadows elicit no response.

In these experiments we again get the maximum of response from mussels which have been kept in running water. In standing water not frequently changed the closure of the siphons is not so rapid in bright light, so easily produced in subdued light, nor so quickly repeated on second stimulation. The siphons do not close so completely, and reopen more quickly. A certain indifference to stimuli, not unlike fatigue, is seen when the water is very impure.

As shown above (Experiment 1) the Unionids kept at south windows very promptly take to burrowing. This is well brought out in the case of *Quadrula heros*. *Lampsilis ligamentinus* and others are very alert. A similar reaction can be obtained at north windows. But it is much slower and does not always occur. The degree of turning is usually less, and the direction of movement less uniform.

Light might be expected to affect the tonus of the siphons, thus determining the size of the apertures, and aiding in the regulation of the flow of water. But such does not prove to be the case. When other conditions are made as nearly equal as possible, it is found that a mussel maintains the same siphon aperture whether in direct sunlight, shadow, or darkness. When carefully changed from one light intensity to another, or when masked and unmasked, there is a brief closure. But the animal sooner or later becomes adjusted to the changed intensity and reopens the siphons to about the same extent as before.

(3) *Phototropic Reactions in Nature.*†

(a) Light *initiates* movement, (b) *orients* movement, and (c) rapid changes in light *affect the siphonal aperture.* These conclusions have been derived experimentally, and under controlled conditions. In the more complex life of a lake or stream the reactions are less easily predictable.

A mussel in too shallow water is exposed to unusual illumination. Light may be a constant stimulus to locomotion until deeper water is reached. Thus the first conclusion is in harmony with the mussel's requirements in nature. The trails of moving mussels show more or less trial and error in the finding of deeper water. If light were the sole directive agency you might expect to find all the mussels of a level stretch of shallow bottom to be moving in the same direction. That such is not the case is doubtless due to the other physical, chemical, and physiological conditions.

It is improbable that light is the sole factor even in the rare cases where a well-defined light gradient exists. Abrupt light gradients seldom occur except accompanied by sharp gradients in depth or turbidity. In the former case pressure enters as an important factor. Only in turbid water or in the presence of shadows is it likely that the conditions of the experiments are approximated closely enough to obtain pure phototropic reactions.

---

†The recent paper of Coker, Shira, Clark, and Howard (1921) has come to hand just as the present manuscript is ready for publication. Their observations have led them to the same conclusions as my own, except that they prefer to regard the depopulation of shaded areas as positive reactions to light of moderate intensity.

The bivalve is vulnerable only where not covered by the shell. It is particularly important to guard the siphons against invasion. Hence their prompt closure even with the passing of a shadow. No doubt enemies and large objects are excluded in this way. The spurting of water is the means of driving away a persistent animal or bulky floating object.

It is possible that the comparatively sparse population of *Potamogeton* beds is due to the checkered light on the bottom. Of course the shadows of surface objects are much diffused at the bottom. The *Potamogeton* bed is more difficult to traverse than open bottom or *Chara*. Yet it is conceivable that the flickering light may keep a mussel more or less in motion until more evenly illuminated bottom is reached. At any rate the interiors of many beds of plant are devoid of mussels, and the margins more populous than the interior. An experiment (Allen, '21, 2) in which a lot of forty marked mussels all escaped after being planted in a *Potamogeton* bed at a depth of three and one-half feet, may be explained thus. Several areas of Winona Lake have during recent years shown great increase in *Potamogeton*. Invariably the number of mussels is correspondingly decreased. Some beds are virtually abandoned.

(d) *Hydrostatic Pressure.*

Mussels were kept in aquaria and tubs in their normal posture upon sand, and otherwise behaving normally. Then the water was gradually siphoned away so as to reduce its depth several inches. Numerous individuals were incited to spurt water and burrow. The reaction has been seen with such frequency wherever mussels are handled as to leave no doubt that there is a pressure sense, and that a mussel tends to seek its optimum depth—at least the depth to which it is temporarily adjusted.

During the early summer of 1919 Winona Lake was deeper than in many previous summers—perhaps two feet higher than its observed previous minimum depth—due to rains and to the construction of a dam at its outlet. The mussel population of its shallow wave-cut terrace was therefore subjected to an increase of pressure of from 10 to 100%. Many of them had moved toward shore, as was evidenced by the long, zig-zag tracks, and the presence of the animals at the shoreward end. Two weeks later the lake had gone down more than a foot.

Many new tracks were then traced, and the makers found at the deeper end. Evermann and Clark ('17) make brief reference to this behavior as of seasonal occurrence in Lake Maxinkuckee.

The matter was checked up experimentally by planting mussels well inshore. Those facing the lake sooner or later moved out. Others facing the shore at first moved inward, but finally turned and went out.

On the low gradients of the wave-made terraces the above responses were slow, and often more or less random. On the very level areas no preponderance of mussels pointing in either direction was discernible. It was desirable to repeat upon a sharp gradient. The sand bank of the Sugar Creek delta has such a gradient—about 30°, more or less. Mussels were planted at a depth of two feet in normal posture, and faced both toward and away from shore. The outcome was much the same as above, but the response took place within a few days. There was much less random movement on the part of those facing shore; they turned very sharply toward deeper water, usually describing an arc of about a foot in radius to make the turn.

This bit of shore is well exposed to wave action—the only other element except pressure or light which might have oriented the movements. That it was not wave action is amply shown by many cases where the same reaction took place in sheltered coves. Light is eliminated by the fact that in this case the siphons were oriented toward the meridian sun in the act of turning toward deep water, a result which is the exact reverse of that in Experiment 1. This and many other observations indicate that where light and pressure are opposed, the latter proves the more potent stimulus.

The forty marked mussels mentioned in the above section may have been incited to movement by changes in depth.

(e) *Equilibrium, Shell Weight, and Posture.*

That bivalves possess an organ of the lithocyst type for maintaining an orientation with respect to gravity has long been known. The stereotyped conception of this function represents the animal as lying on its side, putting its foot out laterally, securing a leverage on the substratum, and pulling itself erect. This is accurate enough in the main, but does not take all cases into account. The posture and manner of

burrowing vary considerably. Thus the organ of equilibrium serves to keep one species perpendicular, and another horizontal or oblique.

The *Lampsilis* and *Unio* species usually have the erect position, while the *Quadrulæ* tend to lie prone. (1) Variation in posture is closely associated with (2) shell weight, (3) with mobility, and (4) with metabolic activity. At one extreme we have the very heavy shell of *Quadrula*, at the other the very light one of *Anodonta*. *Quadrulæ* are extremely sedentary, *Anodontæ* active. *Quadrulæ* nearly submerge themselves in the substratum, *Anodontæ* sit high in the water, the shell sinking only a little way. *Anodonta* exposes its siphons boldly, is the most sensitive of all the Najades to stimulation upon siphon and mantle edge, and of all the Najades is the only one which exhibits a sensitiveness upon the entire mantle surface through the shell. *Quadrula*, on the other hand, does not extend the siphons beyond the shell, does not have so well-developed siphonal papillæ, and reacts very slowly to stimuli. *Anodonta* recovers from stimuli and resumes siphoning most promptly, while *Quadrula*, when caused to close the shell, may remain sealed up tightly for hours. *Anodontæ* kept in aquaria, die most quickly of all mussels when conditions are not kept right. In fact when miscellaneous mussels are kept indoors, even under the most favorable conditions possible, the *Quadrulæ* survive most of the others.

The thin, translucent shell of *Anodonta* is accompanied by a more widely distributed light-sensitiveness. Experiments such as the above show a certain avoidance of the light, but have a less marked orientation than *Q. heros*. The thick shell and well-shaded siphons of the latter admit light from virtually a single direction, making it perhaps the most favorable for such studies of light orientation.

The above points of structure mark the *Anodonta* as a lake dweller, *par excellence*, and *Quadrula* as a river form. *Unio* and *Lampsilis*, of more generalized type, are more readily adaptable to either situation. Representatives of the several genera have taken on divergent habits, however. *Q. rubiginosa* inhabits lakes, and affects the upright position. Yet it has a rather heavy shell and is quite sedentary. When planted experimentally it does not move far. In aquaria movements of the several species accord somewhat with the surroundings, and somewhat with the habits of the species.

In moving water there may be less need for locomotion than in lakes, and less movement actually seems to take place. The constant change of water is the equivalent of changing locality. Isely's observations ('13) have shown that a mussel may remain upon the same spot for long periods of time, in streams.

Deep burrowing forms are much commoner in streams. The principal activity necessary to river species is to keep the siphons at the right distance from the substratum despite shifting bottom, etc. *Plagiola elegans* submerges entirely beneath the surface of the sand. Marine clams, Sphaeriidæ, etc., in like situation elongate the siphons to reach the surface of the substratum. This species, like the ant lion, maintains a little crater whose center is at the siphons, and whose shape is dependent on the angle of rest of the sand. Silt and rolling sand are kept out by spurts of water from the mantle chamber. *Lampsilis anodontoides* is of a more generalized genus which has taken on a form comparable to *Anodonta*, except for its shell thickness. This is considerable and marks the species a river mussel, as well as assigning to it the deep burrowing habit. It also communicates with the water above through a crater-shaped pit. The siphonal papillæ radiate out from the center and rest upon the floor of the crater. In this position they perform their sensory functions and at the same time hold back the sand from the siphons. With the shell thickness and burrowing habit of this species, as well as the *Quadrulæ*, may be associated the less delicate perception of stimuli. *L. anodontoides* accepts much more carmine into the mantle cavity than do other *Lampsiles*. Burrowing species less promptly renew the crystalline style after starvation (Allen, '21, 1).

Résumé.

The foot, mantle, and siphons bear tactile organs, whose abundance is in the reverse of the order named. Their principal functions are the orientation of movements with respect to the substratum and avoidance of enemies. Certain local reflexes exist which do not pass beyond the immediate stimulated region. The innervation of each half of each siphon is independent, and from the splanchnic ganglion. The ventral siphon is the more sensory; the dorsal is the motor termination of many reflexes which have their receptors in the ventral siphon (and in the osphradium). The dorsal has more to do with the regulation of water flow. The

papillæ of the siphon margin are the most highly sensory of all areas. They are employed variously—in guarding the siphon, in gauging the depth while burrowing, and in holding the sand back from the siphon.

There is often an orientation in response to current that holds the bivalve to a definite course.

The mantle, and especially the siphons are pigmented and light sensitive. Experiments show clearly a negative phototropism in bright light, and an orientation of posture and movement with respect to light. Low intensities of light may incite movement without orienting it. The reaction to moving shadows is obviously one of avoidance of enemies and debris.

The magnitude of reactions is dependent in part upon temperature and oxygen. Light does not determine the permanent aperture of the siphons.

A sense of pressure exists by which the optimum depth adjustment is made. When conflicting with other senses, that of pressure is shown to predominate. Reactions to gravity vary in the species in harmony with the posture habits.

4. Chemical Stimuli.

Experiments were made to ascertain the reactions to varying strengths of several acids and bases. No attempt to determine the differential effects of the respective reagents was made, but only the types of reaction and location of the receptors.

The reagents were brought into contact with the epithelia through a finely drawn pipette. The latter was manipulated very cautiously so as to eliminate possible mechanical stimuli through pipette or solution. The mantle edge and both siphons were tested; other epithelia by causing the reagents to enter with the incurrent water by carefully introducing the pipette through the center of the siphon far enough to prevent contact with the siphons themselves.

The best series of reactions was obtained by the use of acetic acid, ammonium hydroxide, carmine, and foul water from decaying Spirogyra, and hay infusions.

Drops of 1.0% acetic acid were applied at several points on the outside of the respective siphons and mantle edge beneath the siphons. In all cases there was a rapid closing of both siphons and a rapid and violent discharge of water.

When siphoning was begun again, the point which had been touched with acid was found to be drawn back sharply—even sometimes the entire half siphon, and this effect was perceptible after several hours.

If while still under this initial stimulus 0.1% to 1.0% acid was administered, the animal still responded, but much less promptly. The effect of the 0.1% acid was of much less duration, but at first of equal magnitude.

Very few animals gave any response to the acid of 0.01% more or less, when applied to either mantle or siphons.

By the use of ammonium hydroxide a similar scale of responses was obtained; 0.5% evoked a very rapid and profound response—even in mussels that had been very inactive. The effect passed much more rapidly than in the case of the 1.0% acid. 0.1% ammonium hydroxide had a great effect upon the same individuals just recovering from the stronger alkali, but more effect on fresh animals. 0.01% obtained a very slight and tardy response. When given in water of low temperature—12° to 14° C.—0.01% gave no reaction whatever.

From the above it is clear that the mantle edge and siphons are provided with organs of chemical sense, which are keenly sensitive to acid and alkaline substances of high concentration. The response was equal in the case of the ventral siphon and of the subjacent mantle edge, but noticeably less in the dorsal siphon.

Carmine and foul water elicit no reaction from siphons or mantle edge, as was true of all very low concentrations.

The osphradium has been known as an organ of chemical sense, largely from its structure. Before water may be tested chemically it must first pass through the ventral siphon, the mantle chamber, the gill chambers, and the suprabranchial chamber. At first thought the position of the osphradium under the visceral ganglion seems remote and futile, since the character of the water may not be known until just before leaving the animal. Conversely it may be of some advantage to have all the water pass a common point such as this. However it is probable that the osphradium is phylogenetically a more ancient structure than the siphons, and long associated with the visceral ganglion—hence its position there rather than upon the neogenetic mantle structures. The mussels of lake or stream seldom encounter solutions of great concentration.

When dilute, their diffusion is sufficient to cause a closure of the shell before much harmful matter can enter.

The following tests of the osphradium were made to determine whether it possesses chemo-receptors, and if so their relative sensitiveness, compared with those of the mantle and siphons.

The finest carmine, pipetted from the upper levels of a carmine suspension which had settled for several days, was introduced into the ventral siphon. There was no response from the siphons. Just before the carmine could be seen to have reached the dorsal siphon, there occurred a quick closure of the ventral siphon, followed by that of the dorsal, and a prompt reopening of both. Thus it is seen that the carmine had not affected any sense organs until it had nearly reached the dorsal siphon—the location of the osphradium.

Stale water and infusions were never found to affect the chemo-receptors of the siphon and brought about no reaction until they reached the osphradium.

There was still the slight possibility that the gills or mantle might possess organs of chemical sense. Therefore to produce a more marked effect upon the osphradium alone than is possible by introducing reagents into the siphon with respiratory water, the following experiment was tried.

A few drops of 1.0% to 10.0% acetic acid were drawn into a fine pipette, the latter inserted into the dorsal siphon just far enough to reach the osphradium, the acid discharged and instantly drawn back again into the pipette with considerable water from the suprabranchial chamber. Thus it was made sure that the concentrated acid affected the osphradium region only, and that only very dilute acid if any reached the dorsal siphon. The following results were noted:

(1) Neither siphon fully opened within a week or more, though the water was purposely allowed to grow stale sometimes.

(2) The papillæ of both siphons remained in contraction.

(3) Vigorous burrowing, and frequent spurting.

(4) Both siphons still very sensitive to dilute acid.

(5) The osphradium was still sensitive to dilute solutions; not all its receptors had been destroyed or paralyzed.

Another test consisted in isolating the osphradium from the outgoing current. This was accomplished by lowering the water level to a point just sufficient to flood the floor of

the suprabranchial, and so as to leave the osphradium above the surface. As soon as the animal had ceased spurting and grown accustomed to the water level, and accustomed to having the posterior end out of water, the fine carmine suspension previously mentioned was introduced into the still submerged ventral siphon.

A stream of carmine could thus be kept passing through a mussel for an indefinite length of time. The siphons were not adjusted to register so nearly neutral a reagent. When the water level was raised again slightly and the osphradium flooded the usual response to carmine again took place.

These reactions verify the usual conception of the function of the osphradium, and show something of its range.

5. Tonus of the Siphons.

It has been seen that mechanical stimulation and light exert no permanent influence upon the muscle tonus of the siphons and regulation of the streaming. Chemical stimuli do have this function. Mussels placed in water containing little oxygen maintain always a much wider aperture. As noted previously this is the more pronounced in the case of the dorsal siphon.

When the water is greatly fouled by material in decay, the siphons (especially the dorsal) more or less completely close. Entire closure may result in such inactive mussels as *Quadrula heros*, but rarely so in the more active *Anodontæ* or *Lampsiles*.

6. Accessory Siphons.

When under conditions of deficient oxygen not only do the siphons widen to their greatest extent to bring in more water, but also additional spaces between the mantle edges are thrown open. In most species there occurs a very definite accessory dorsal siphon, the *supra-anals* of Ortmann ('12) above the dorsal. It is not provided with papillæ, and is not so sensitive to the various stimuli enumerated above. It is only opened in emergencies; uncommonly under normal conditions. In the several species the supra-anal varies in its length, and in its distance from the dorsal siphon. Likewise there is a variation in the extent of the cloaca above the suprabranchial channel. It reaches its maximum dimensions in

Quadrula heros or *Lampsilis alatus*, whose mantle extends dorsad to the full extent of the *ala*. The ciliary movement of the cloacal portion of the mantle is ventrad and centers at the dorsal siphon—not the supra-anal. The higher the shell and mantle extend above the siphons, the longer is the accessory siphon of the several species.

Ventral to the incurrent siphon other temporary openings may appear between the mantle edges. Rarely (in extreme exhaustion) this opening extends the full length of the mantle. When the siphons have been injured or over-stimulated, and when they lie above the surface of the water, the mantle is allowed to stand open along its ventral margin.

Résumé.

It was shown by experiment that the siphons and mantle margin are subject to chemical stimulation only of considerable concentration. Lower concentrations take effect through the more sensitive osphradium. Since high concentrations do not ordinarily concern the animal in its normal habitat, the chief sensory functions of the siphon are those of physical character. By means of the osphradium the mussel reacts to very small changes in the chemical nature of the water. The muscular tonus of the siphon and mantle is under control of the chemo-receptors of the osphradium. Through the resulting apertures of the siphons, and occasional accessory openings of the mantle, the regulation of water flow is accomplished. Normally the ventral siphon has a more constant aperture, while the streaming is controlled by the anal.

7. Concluding Remarks on the Nervous System.

The siphons, due to their exposure, and to the intake of water, have attracted a large share of mantle musculature, and with it the richest share of motor and sensory nerve endings. These center at the splanchnic or visceral ganglion. So far as the "conscious life" of the mussel has come to center about the siphons and osphradium, the visceral ganglion is physiologically the brain. In the sense that cephalization is usually accompanied by corresponding development of a cephalic ganglion and cephalic sense organs, the visceral ganglion has largely taken over these functions in the mussel which communicates with the outside through posterior siphons. To be sure the cephalic ganglion still retains two pairs of commissures in

communication with the other ganglia, but its sensory functions are of a less peripheral character than those of the visceral.

By virtue of homology and position at the anterior extremity of the body the cephalic ganglia are entitled to their name. They possess little analogy to a true cephalic organ.

That the mantle and visceral innervation of the mussel is divided about equally between the cerebral and visceral ganglia, and that the two ends of the animal are rather independent of each other, is shown by the following experiment:

The two valves were wedged one-fourth inch apart by a fulcrum of wood at the center of the ventral margin. The point was selected where the pull of the two adductors just balanced each other. Then the two ends of the mantle and visceral mass were prodded by turns. By turns there was a greater adduction at the stimulated end. This was sufficient to overcome the already vigorous contraction of the other adductor, and caused the relaxing end to gape more widely. Additional stimulus at either end overcame the balance. The magnitude of the response decreased progressively as the stimulus was applied nearer and nearer the block, where the branches of the pallial nerves overlap and anastomose. The narrowness of the mollusk's existence is much expatiated upon. The principal reactions of the bivalve when summed up include only: Protraction and retraction of the foot, adduction of the shell, protraction and retraction of the mantle margin and siphons. The movements of locomotion and burrowing, respiration, waste disposal, and driving away of intruders are chiefly made up of combinations of these five reactions, supplemented by ciliary activity. It is as though the whole existence of a mammal were made up of stretching, yawning, and sneezing. Usually more than one of these reactions follows a considerable stimulus. After many observations one can become more or less skilled in predicting from the manner of a movement just what will follow it. For instance, in the way of closing the shell one can foretell that burrowing will ensue. When the siphons are opened in a less cautious way, one may predict that the animal is about to "sneeze"—i. e., spurt water through the siphonal region.

In many of the activities of the mussel cumulative movements are seen. The initial stimulus is insufficient to incite the entire series of movements directly. Only a small portion of the foot or siphon may be set in motion at first, then in wave-

like fashion the contraction passes on and engages all parts of the organ. Local reflexes are probably responsible for this behavior, for it is observable even in a foot or siphon which is dissected out and not in communication with the central nervous system. The contraction of one region stimulates the adjacent areas, and they in turn by contracting pass the movement onward.

Three elements at least have contributed to the degenerate character of the bivalve nervous system:

(1) The aquatic life; comparative uniformity of the physical and chemical environment. New and difficult conditions have not often confronted them. The advent of the industrial period, and stream pollution have found them unprepared except as to great fecundity.

(2) The nearly sedentary life, passive feeding habits, and slight need of locomotion.

(3) The sheltered existence within the shell, and passive immunity from attack by enemies.

LITERATURE.

Allen, W. R.
1914. The Food and Feeding Habits of Freshwater Mussels. Biol. Bull. 27, 3; pp. 127–139.

Allen, W. R.
1921. Studies of the Biology of Freshwater Mussels. Two papers:
(1) I. Experimental Studies of the Food Relations of Certain Unionidae. Biol. Bull. 40, 4; pp. 210–241.
(2) III. Distribution and Movements of Winona Lake Mussels. Proc. Ind. Acad. Sci.
The present paper forms No. II of this series.

Coker, R. E.; Shira, A. F.; Clark, H. W.; and Howard, A. D.
1921. Natural History and Propagation of Fresh-Water Mussels. Bull. U. S. Bur. Fish., 37, Doc. No. 893.

Evermann, B. W., and Clark, H. W.
1917. The Unionidae of Lake Maxinkuckee. Proc. Ind. Acad. Sci., pp. 251-285.

Grier, N. M.
1919. Morphological Features of Certain Mussel-Shells Found in Lake Erie, Compared with Those of the Corresponding Species Found in the Drainage of the Upper Ohio. Ann. Carnegie Mus. 8, 1–2; pp. 145–182.

Grier, N. M.
1920. Variation in Epidermal Color of Certain Species of Najades Inhabiting the Upper Ohio Drainage and their Corresponding Ones in Lake Erie. Amer. Midland Nat. 6; pp. 247–285.

Hecht, S.
1921. The Photochemistry of the Sensitivity of Animals to Light. Sci. 53, 1372; pp. 347–352.

Isely, F. B.
1913. Experimental Study of the Growth and Migration of Freshwater Mussels. Bur. Fish. Doc. 792.

Ortmann, A. E.
1912. Notes upon the Families and Genera of the Najades. Ann. Carnegie Mus. 8, 2; pp. 221–365.

This paper received for publication April 17, 1922.

MINERALIZATION ALONG THE DIKES OF SOUTHERN VERMONT.*

HARRIET G. BRAY and ALDEN H. EMERY
Oberlin College, Oberlin, Ohio

INTRODUCTION.

The region covered by this study lies in southern Vermont about fifteen miles north of the Massachusetts boundary line. Wilmington, latitude 42° 52′ N., longitude 72° 52′ W., in Windham country, was about the center of the field of operation. Most of the work done was between the parallels of 42° 45′ and 43° N. and the meridians of 72° 45′ and 73° W. The majority of the work was done in the township of Wilmington, although adjoining townships were partially covered.

The country rock of this region is predominantly a quartz-mica schist which varies greatly both in structure and composition. As regards structure, it is found with both slaty and gneissic forms, although it is typically an ordinary schist. It is much folded into anticlines and synclines, some of which have an axial length of several miles, and it also has profound local contortion and severe crumpling. In composition the range is from almost pure quartz to almost pure mica, with fifty per cent of each as the typical combination. The mica is generally biotite, but it is sometimes accompanied by muscovite, paragonite, and in rare cases, phlogopite. The quartz is almost always colorless or milky, but it is occasionally pink, due to the coloring properties of some compound of iron in minute quantities. The range of composition is further varied by the addition of accessory minerals, the most common of which are feldspar, magnetite, pyrite, and limonite pseudomorphs after pyrite.

The whole region is shot full of semimetamorphosed dikes of diorite and of later quartz or quartz-feldspar dikes, which often cut through the diorite dikes and seem to pay even less attention than they do to the structure of the country rock and its planes of schistosity. The outcrops of the dikes vary in width from a

* The authors are deeply indebted to Dr. George D. Hubbard, head of the Department of Geology and Geography of Oberlin College, for valuable assistance both in the field and in the laboratory, and for suggestions on this manuscript.

Presented before the Geology Section of the Ohio Academy of Science April 14, 1922.

few hundred yards to two or three miles. The quartz dikes vary in size within wider limits than do the diorite and send out stringers into the country rock much more extensively. Although nothing is known of the mass or masses of magma in which these dikes originated, it is extremely probable that they came from the same magmatic basin and that they form a series of complementary dikes which, if mixed in amounts proportional to the quantity in which they occur, would give the chemical and general mineral composition of the original large mass. Thus the variation in composition of the dikes is assumed to be due to variation in composition of the magma or sub-magma at different periods.

DESCRIPTION OF DIKES.

The typical composition of the diorite is one of nearly 70% of hornblende, about 30% of feldspar with quartz in varying quantities, and some iron-bearing mineral, either pyrite or magnetite, in slight amounts. The range of composition is from an eighty-twenty relation of the essential minerals to one of fifty-fifty, innumerable variations occurring between the two. The rock is generally very fine-grained, with the feldspar and quartz arranged in spheres or circles scattered evenly throughout the rock. At times the feldspar and quartz bunches are so fine that they are discernible only under the microscope. In rare cases the centers of these quartz or feldspar spheres are hollow, but generally they contain biotite, magnetite, pyrite, limonite pseudomorphs after pyrite, or very good hornblende crystals. In a case where biotite occurred in the center of the quartz spheres, a microscopic study of the specimen showed a zonal arrangement of the two minerals. The outer shell of the sphere consisted of quartz with only microscopic crystals of biotite, the next had quartz and biotite in about equal amounts, evenly intermingled, and the center consisted of almost pure biotite. A careful microscopic study of other minerals found in the center of feldspar and quartz bunches would probably show a tendency toward the same sort of zonal arrangement. The same minerals which occur in the centers of the feldspar circles generally occur scattered throughout the diorite itself in minute ill-formed crystals. Only in one or two cases did the biotite occur with sharply defined crystal angles or the magnetite with perfectly triangular octahedral faces.

The acidic dikes and stringers are usually nearly pure milky quartz. Quite often they are of quartz and feldspar in varying proportions, and the feldspar occurs in various-sized blotches surrounded by quartz, into which feldspar stringers sometimes extend. This silicate may be light-gray oligoclase or white albite, but is generally a pink feldspar which has been proved by the petrographic microscope, in all cases studied, to be pink microcline. This bears out Pirrson's theory that the potassic feldspars are pink due to finely disseminated iron oxides because potash does not readily enter into combination with iron. In connection with the results of mineralization found here, it may be interesting to note that he believes the gray color of oligoclase to be due to finely divided ilmenite disseminated through it. Sometimes there is more feldspar than quartz in these dikes, and in one or two places small irregular stringers of practically pure feldspar were found.

MINERALIZATION.

The mineralization along these dikes is extensive, as might be expected, but the quartz and quartz-feldspar dikes have a much greater amount of it because the most active volatile constituents of a magma, such as Ti, Cl, Fl, B, and the hydroxyl and sulphate radicals, seem to accompany the acidic rather than the basic sub-magmas.

Practically the only minerals found in and near the diorite dikes as the result of mineralization are pyrite and magnetite, although some of the unusually large and well-formed biotite crystals which are found in places in the diorite may have been influenced to some extent by mineralizers. The magnetite is usually disseminated through the dike itself in small indistinct crystals of microscopic size, though sometimes it occurs in aggregates of these crystals, and occasionally in single good-sized perfect octahedrons. In the country rock, the magnetite crystals are generally fewer in number, but better developed. The pyrite is almost always in single well-formed cubes of various sizes, both in the dike and in the country rock, but it is much more apt to be concentrated along the contact than the magnetite, and frequently occurs in aggregates of crystals there. Occasionally a large pyrite crystal is found including a smaller one of magnetite. Very often the pyrite is completely altered to limonite pseudomorphs before any other sort of weathering is apparent.

Occasionally inclusions of the schist in the diorite dikes and portions of the schist close to the contact contain good crystals of hornblende and feldspar. The presence of these minerals in the dikes is not due to mineralization, but their occurrence in the country rock is undoubtedly due to it. A further evidence of mineralization along these dikes is in the finding of rare crystals of paragonite and phlogopite, always found close to the contact in the country rock.

Mineralizing gases may by their presence influence crystallization or recrystallization without entering into direct combination, and it is possible, if not probable, that much of the fine crystallization of minerals within the feldspar spheres of the dikes is the result of this influence.

It is along the quartz and quartz-feldspar dikes, however, that the best and most abundant evidences of mineralization may be found. The range of minerals occurring along this class of dikes is much greater than that of the diorite dikes. It includes biotite, muscovite, the hydrous green micas, ilmenite, magnetite, pyrite, tourmaline, actinolite, epidote, hornblende, and others. The mineralization which results in some form of mica is by far the most common, and of these micas, the most common form is biotite. It occurs in good crystals along the contacts and extends into the dikes and country rock either side of the contacts. In the dikes, the crystals are conspicuous by reason of the contrast in color, but in the country rock they merely make the schist look darker and denser near the dike, due to this increase in the amount of biotite. In one exceptional case some beautiful large crystals were found in the very center of a quartz dike. This phenomenon was probably caused by the rapid cooling of the quartz which left cavities where the biotite crystals were formed and were later surrounded by an inflow of quartz in heated aqueous solution.

Muscovite, for some reason, is very rare. In a few cases, it occurs in small flakes with some other true mica, and in only one case it is known to occur in beautiful large and distinct crystals in a quartz dike. Phlogopite is as rare here as in the diorite dikes, but paragonite is more common and occurs with muscovite in several places in the schist, near contacts with the dikes. It also occurs in bunches of fine crystals in the quartz of the dike itself, and in one such occurrence where the crystals are strung out along the contact between the quartz

and the feldspar, it is noticeable that the contact between the quartz and the mica is much sharper than that between the mica and the feldspar. In fact, inclusions of crystals of the mica in the feldspar and the reverse are common, while such a thing is almost never observed in the quartz.

The hydrous green micas are widely found in the schists. Penninite occurs with a pearly lustre and appearance so closely approximating that of biotite that a hasty examination does not disclose the difference. Chlorite is often found and comes both from hornblende and from biotite, as evidenced by its general form and its associations.

Tourmaline is found almost everywhere along the dikes. It generally occurs in small distinct needles disseminated in the country rock near the dikes, but occasionally it occurs in single crystals and in aggregates of crystals whose dark color is sharply contrasted with the white of the quartz matrix. Epidote is not very common and generally occurs in rather a massive form between the country rock and the dike. Large masses of beautifully crystallized actinolite, associated with quartz, are found in such quantity that it must be assumed here, as perhaps for the epidote above, that the largest part of the basic material for the mineral was already present in the country rock and that the mineralizers merely changed its form or perhaps added to it other elements in slight amount.

Ilmenite occurs in medium amounts, almost always within the edges of the quartz dikes themselves, sometimes along the contact, and rarely within the country rock. It is not usually in good crystals, but occurs in plates as much as two inches long. Magnetite is much more common than the ilmenite. As is the case near the diorite dikes, the magnetite is apt to be disseminated through the country rock near the contact in small, imperfect crystals. It also occurs in the quartz-feldspar dikes themselves in good crystals, as well as in aggregates. Pyrite is also very common and has much the same sort of occurrence as does magnetite. It is apt to be better crystallized though, especially in the dikes. In one case it occurs in especially large good crystals scattered through a quartz dike, and the crystals are twinned and ribbed in a peculiar manner.

In several cases it is noticeable that in a quartz-feldspar dike, the contact between the feldspar and the country rock is much less sharp than between the quartz and the country rock.

An analagous difference in type of contact between these two minerals and crystals of mineralization has also been noted, and in one or two cases a pure quartz dike is accompanied by almost no effects of mineralization whatever. It may be that some part of the feldspar acts as a mineralizer itself or that the feldspar as a whole is simply more active when crystallizing than the quartz is. It would take a much more detailed study than this to arrive at any conclusion which could be put forth with any assurance as to its correctness.

SUMMARY AND CONCLUSIONS.

To recapitulate: the two types of complementary dikes found in this region in southern Vermont, of diorite and quartz and quartz-feldspar, are accompanied by extensive mineralization. The type of alteration found in the country rock near the contacts is much the same in many respects for both kinds of dike. The quartz and quartz-feldspar dikes, however, have much the longer list of minerals resulting from mineralization since the more volatile constituents of a magma seem to accompany the acidic rather than the basic sub-magmas. The common minerals thus formed are hornblende, actinolite, tourmaline, biotite, muscovite, phlogopite, paragonite, pyrite, magnetite, ilmenite, and others.

There is much undoubted mineralization which, so far as we can see, is associated with no dike at all, but which should serve as a guide for further search for dikes.

The descriptions here given and the problems stated are the result of a preliminary and somewhat superficial study of a region almost wholly unknown geologically except in a very general way. It is evident, however, that the region is a very interesting one and offers an excellent field for the study of the results of metamorphism. The work as yet has been barely started, and it is hoped that further careful study by those interested may solve the problems mentioned and many others unmentioned, but undoubtedly present.

This paper received for publication May 25, 1922.

A CORN-FEEDING GEOMETRID

Pleuroprucha insulsaria Guen. (Lep. Geometridæ).

GEO. G. AINSLIE

Entomological Assistant, U. S. Bureau of Entomology

CONTENTS

Introduction 89
Distribution 90
Food Plants 91
Systematic History 92
Seasonal History 92
The Moth 94
The Egg 95
The Larva 96
The Pupa 98
Life Cycle 99
Parasites 100
Other Enemies 100
Literature Cited 101

INTRODUCTION.

In his monograph of the corn-feeding insects (3, p. 173) Forbes remarks on the fact that not a single species of the Geometridæ has been reported as feeding on this plant except an undetermined species mentioned many years ago by Smith (6, p. 188). So far as the writer has found no such report has been made since that time. For several years past, however, various observations have been made on a small geometrid larva occurring in varying abundance from year to year on corn silks. This species, *Pleuroprucha* (*Deptalia*) *insulsaria* Guenee appears never to have received the attention of economic entomologists. The injury it causes is trifling, but as a corn-feeding insect it is worthy of record.

The larvæ were first found in small numbers but well distributed in corn fields in the bottom lands along the Cumberland and Tennessee Rivers in eastern Tennessee, in August and September, 1913. They were again noted at Nashville,

Tennessee, the following year. At Knoxville in 1916, and more especially in 1917, they were so abundant that an excellent opportunity was afforded to study their habits. The data contained in the following article were obtained for the most part at Knoxville in 1917. Full credit and grateful acknowledgement are given to Mr. W. B. Cartwright, my assistant at that time, for his interested co-operation and assistance and also to Dr. Dyar, of the National Museum, for his kindness in supplying me with many of the distribution records quoted below and with a copy of Packard's description of the adult moth.

Pleuroprucha insulsaria Guen.

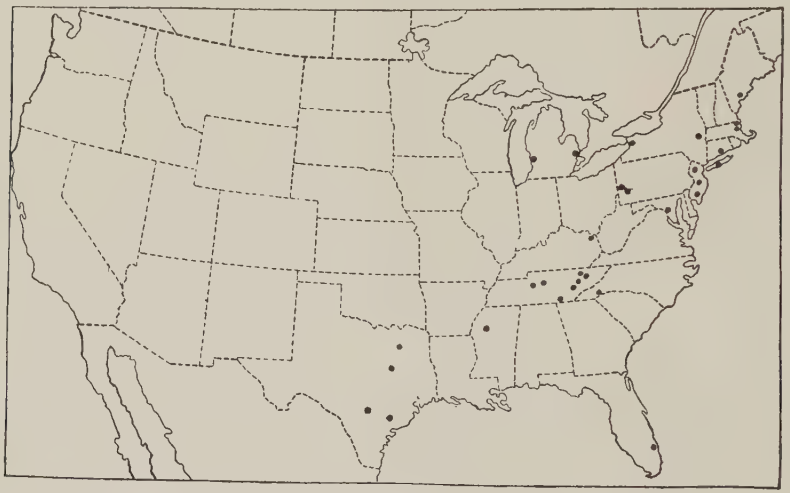

Fig. 1. Known distribution of *Pleuroprucha insulsaris* Guen. in the United States.

DISTRIBUTION.

The writer has taken larvæ of *Pleuroprucha insulsaria* at numerous points in eastern Tennessee and Kentucky and as far west as Nashville, Tenn. There is a note in the Bureau files recording the collection of larvæ on corn silk at Greenwood, Miss. The species is included in Britton's (1, p. 120) check-list of the insects of Connecticut. Smith (7, p. 498) lists it as "common throughout the State" of New Jersey. In his catalog Dr. Dyar gives the distribution as "Atlantic States" and in a recent letter he informs me that he has records from

Texas, North Carolina, District of Columbia, Florida, Pennsylvania, New York and Michigan. He has also given me the known distribution outside the United States, which shows it to occur in Mexico and Central America south to the Canal Zone, and throughout the West Indies. Walker (8, p. 737) also described the same species under other names from Venezuela, Florida and Jamaica. In addition to the states mentioned above Packard (5, p. 335) records it from Maine and Massachusetts. The exact localities when known are indicated on the accompanying map.

FOOD PLANTS.

Fresh corn silk seems, without doubt, to be the favorite food of the larvæ. Thorough search has repeatedly been made of other vegetation, especially of plants with flowers, to find whether any succulent floral tissue would serve as food. In only a few instances have the larvæ been found in such locations and then usually after fresh corn silk had largely disappeared from the fields. On August 31, and again on September 18, three larvæ were found on flowers of a cultivated species of *Helianthus* on which evidently they had been feeding. Other larvæ were swept September 6 from smartweed (*Polygonum pennsylvanicum*) in bloom and again on September 25 six larvæ were swept from flowers of *Verbesina occidentalis*. A single larva was swept from a mixed growth of oxeye daisy (*Chrysanthemum chrysanthemum*) and daisy fleabane (*Erigeron philadelphicus*) on June 12. Two larvæ were also found on flower heads of sumac (*Rhus glabra*) on August 21, and when confined in boxes with this same food they fed by eating small notches in the tender flower stalks. Most of these collected larvæ were reared to maturity so their identity cannot be questioned. Other larvæ quite similar in general appearance were also collected on various flowers, but when reared proved to be other species. Those taken on corn silk were all of this species.

In addition to the food plants observed in the field some cage experiments were conducted. Larvæ were reared nearly to maturity on caged flower sprigs of *Erigeron philadelphicus*, but because of neglect failed finally to pupate. In this case the rays were eaten and possibly the disk flowers to a slight extent. Larvæ confined in a box with fresh flowers of red clover (*Trifolium pratense*), horse nettle (*Solanum rostratum*),

daisy fleabane (*Erigeron philadelphicus*) and strands of fresh corn silk fed only on the corn silk. In another experiment larvæ were confined individually in tin boxes and given flowers or flower clusters of alfalfa, pigweed (*Amaranthus retroflexus*), cowpea, mullein (*Verbascum thapsus*), ragweed (*Ambrosia artemesiaefolia*) and smartweed (*Polygonum pennsylvanicum*) and with leaves of bluegrass (*Poa pratensis*), corn, cowpea, mullein, crabgrass and with anther sacks and pollen of corn, but only those supplied with the corn pollen and the smartweed flowers fed and matured, showing quite conclusively that, although not strictly limited in food habits, the species is far from a cosmopolitan feeder.

Packard (5, p. 335) states that he has reared the larvæ on *Celastrus scandens* and Smith (7, p. 498) in addition lists *Galium*, *Cassia* and oak as food plants, but does not specify what parts of these plants are eaten. Dr. Dyar writes me that he has found a pupa on alder and that in one instance the larva occurred abundantly on golden rod (*Solidago*) brought into the house for decorative purposes.

SYSTEMATIC HISTORY.

The following names and references, kindly supplied by Dr. Dyar, give in brief outline the systematic changes through which this species has gone.

Acidalia insulsaria Guenee, Spec. Gen., 9:469. 1857. N. A.
Acidalia asthenaria Walker, C. B. M., 22:737. 1861. Venezeula.
Acidalia nivariata Walker, C. B. M., 25:1596. 1862. East Florida.
Acidalia imparata Walker, C. B. M., 25:1598. 1862. Jamaica.
Acidalia persimilata Grote, Proc. Ent. Soc. Phil., 1:347. 1863.
Acidalia insulsaria Packard, Mon. Geom. Moths, 335. 1876.
Deptalia insulsaria Hulst, Trans. Am. Ent. Soc., 23:300. 1896.
Deptalia insulsaria Hulst, Bul. 52, U. S. N. M., No. 3477. 1903.
Pleuroprucha insulsaria Barnes & McDunnough, List. No. 3914. 1917.

SEASONAL HISTORY.

Smith (7, p. 498) reports the moths as occurring in New Jersey from June to October. The earliest record we have for Tennessee is May 31, when several of the moths appeared at light. During the summer of 1917 frequent collections were made at light from June 25 to September 26 and the following data on the occurrence and relative abundance of the moths were obtained.

Occurrence and Relative Abundance.

DATE	♂	♀	TOTAL	DATE	♂	♀	TOTAL
June 27	1	1	2	July 28	0	21	21
" 29	0	1	1	" 30	0	3	3
July 4	1	1	2	Aug. 3	0	2	2
" 8	9	6	15	" 4	2	5	7
" 9	0	2	2	" 6	1	2	3
" 10	3	4	7	" 11	1	0	1
" 11	18	26	44	" 13	2	23	25
" 17	32	118	150	" 14	5	36	41
" 19	0	2	2	" 15	1	5	6
" 21	30	505	535	" 20	2	4	6
" 23	5	27	32	" 25	1	0	1
" 26	4	18	22	Sept. 2	3	8	11
" 27	0	3	3	" 5	1	1	2
				" 10	1	0	1

Several of the moths matured in rearing cages between October 6 and 19 and one female moth was taken in the field October 15. The table shows the emergence of two generations of moths, one reaching its maximum about July 21 and the other August 14. There are undoubtedly other generations both before and after these. So much for the moth records.

The earliest larval record is that of one swept from blooming daisies June 12. Larvæ were first found abundant on corn silk July 31, but judging from the moth record they must have occurred much earlier and in great numbers either on corn silk or some other food plant. They remained abundant on corn silk the first half of August and scatteringly until September 10. After August 15 the corn silk had mostly dried and larvæ very quickly became scarce. Occasional individuals were taken on smartweed and other plants until September 25, which is the last date we have for the larvæ.

Just how this species passes the winter is still an open question. That either the egg or the pupa stage can be so greatly prolonged seems impossible. The adults are never seen during the winter, as they surely would be if they survived, so the larvæ must pass the winter either fully or partly grown. Further observations are needed to subtantiate this theory.

To summarize, the seasonal history, as far as facts are available, seems to be as follows: In the spring the few individuals surviving the winter become active. The larvæ lead a precarious existence, feeding on flower tissue of various plants practically in the open and exposed to the attacks of birds and

predaceous and parasitic insects. Until corn silk becomes available the species does little more than maintain itself. With the widespread appearance of fresh corn silk which furnishes at once not only an abundant and suitable food supply, but shelter and protection from enemies as well, the insect is enabled to increase to enormous numbers almost in a generation. The silk persists long enough for two generations to develop. With its disappearance the former hazardous conditions again prevail and the species is quickly reduced to negligible numbers. That the same degree of abundance is not reached every summer may be due to unfavorable winter conditions cutting the number of survivors almost to the point of extermination or to the presence of other and more effective parasites than the *Apanteles* noted below.

THE MOTH.

Description. A delicate luteous species with very triangular wings, especially the hind wings which are short and on the outer margin much less convex than usual. Antennæ and space between silvery-white, in the male pectinated on basal half; front of a peculiar greenish tawny hue; palpi pale, slender, upcurved and passing beyond the front. Both wings alike, luteous with an almost imperceptible greenish tinge, flecked irregularly with darker scales, without any distinct lines, except an obscure, fine, white, waved, submarginal line dotted with black on the venules, discal dot represented by raised scales, edge of both wings dark (?), slightly scalloped, fringe very long, slender, a little unequal; beneath paler, with marginal and submarginal rows of rufous venular points. Length of body, ♂ 7.5 mm., ♀ 7.0 mm.; of fore wing, ♂ 10.5 mm., ♀ 9.5 mm.; expanse of wings, 18.75 to 21.25 mm. (Revised from Packard).

HABITS OF THE MOTHS.

The moth is nocturnal in habit and spends the day hidden under some leaf, flying only if disturbed. At rest its wings are always outspread and closely flattened to the surface. The sexes are easily distinguished by the antennæ, filiform in the female and in the male pectinate from the base for about half their length, the first 15 segments each bearing two unequal finger-like processes. There are several other moths closely resembling this species in size and coloration, but this is the only North American representative of its genus.

The moths come very freely to light but after reaching it do not flutter about but rest quietly nearby with wings flatly

outspread. Among those taken at light the females greatly predominate. Of 200 taken at random on July 21, 1917, 91% were females. Of a total of 958 coming to light of which record was made 834, or 87%, were females. This abnormal ratio is very likely due to the fact that most of the collecting was done before midnight while experience with other species has shown that the males come in much greater numbers after that time. This supposition is further borne out by the fact that among the moths reared, the sexes were very evenly divided. Nearly all the females coming to light were gravid. Only one pair was observed in copulation and they were apparently abnormal for they died still in copula. Practically all the eggs obtained in cages from collected moths proved fertile.

The moths are short-lived. In cages where the conditions were made as normal as possible, the average length of life for 44 moths was 6.4 days with a maximum of 13. The sexes were about equal in longevity.

THE EGG.

Description. Length .512 mm., width .318 mm. Evenly ellipsoidal except for a slight flattening in one plane, parallel with the long axis, and attached by one of these flattened sides. Chorion shining, evenly and coarsely reticulated over the entire surface, there being 12 to 15 of the spaces in the length of the egg.

NOTES ON THE EGG.

When first laid the eggs are pure white, slightly watery. In a few hours they become pale yellow, by the second day mottled, and the embryo can be discerned doubled in the egg in the form of a horseshoe. Early the third day the group of red ocelli can be seen as dark specks near one end and later in the day the dusky striping of the larva shows plainly, giving the egg a dingy cast. The larva emerges in 2½ to 3 1-3 days from the time of oviposition, through a hole near one end of the egg, at the point occupied by the head of the embryo larva. The empty shells are iridescent, colorless, and usually retain their shape.

The number of eggs laid by individual moths varied greatly. Many laid none. For the 60 moths of which record was made the average was 24 eggs. The largest number produced by one moth was 138 and her ovaries still contained eight fully developed eggs when she died. Another laid 125. It seems likely

that the number normally produced by a moth in nature is not far from 100, more rather than less. Dissections showed the ovarioles full of egg cells in various stages of maturity.

Moths confined in cages readily laid eggs. The cage used consisted of a lantern globe with a cloth top set on a disk of blotting paper resting on damp sand and contained a tube vial filled with water and plugged with a wad of cotton in which a small lock of corn silk was wedged. Eggs were laid on all parts of the cage and its furniture. Over 1400 eggs were laid by moths in the various cages, placed as follows: On the corn silk 55%, glass of globe or vial 32%, blotting paper floor 8%, cotton plug 3%, cloth top 2%. In the field eggs have been found only on corn silk or on the husks near the tip, close to the silk.

The eggs laid on glass were so firmly fastened as to be difficult of removal without injury, but those on the cloth, paper or corn silk were easily detached with brush or needle.

THE LARVA.

Description. Newly hatched larva. Length, extended, 1.632 mm., head width .194 mm., body width .141 mm. Head rather broad, whitish, with acute hairs on face, three of the ocelli red, the other three pale. Thorax as broad as head cephalad, narrowing caudad, pale yellow. Abdomen slender, the segments as long as broad except the last three shorter and the last one much broader, with two pairs of prolegs on the sixth and last segments respectively, the crochets brown. Abdomen very pale yellow laterally, slightly dingy above and below, the dorsal dingy area margined on each side by a narrow brown stripe which becomes obsolete on the thorax and on the last abdominal segment, which is paler than the rest of the body. The thorax and abdomen bear short capitate hairs laterad. The larva is a pronounced looper throughout its entire life.

A lot of larvæ taken from corn silk were measured and easily sorted into five instars whose head measurements are tabulated below:

	HEAD WIDTH		
INSTAR	MAXIMUM	MINIMUM	AVERAGE
I	.194	.194	.194
II	.300	.282	.291
III	.477	.441	.459
IV	.688	.600	.644
V	1.024	.918	.971

The fourth instar larva was described as follows: Length, 11 mm. Entire body, including head, longitudinally striped with narrow nearly continuous more or less broken stripes of brown, yellow, gray and pink, more or less mixed with whitish, the dorsum darker than the spiracular stripe which usually contains considerable white. Ventral surface like the rest with the median stripe paler except the surface between the prolegs pale and unmarked. Head striped like body, but paler about mouth parts, pale ventrad. Tubercles on dorsum small, black, those on the side pale, all with short black setæ. Prolegs on sixth and ultimate segments with a single row of large crochets on inner margin.

HABITS OF THE LARVÆ

The larvæ are inconspicuous on the locks of corn silk and ssem to be colored to match their habitat. They vary from pale yellow and green through orange, red and brown to jet black, the ventral surface usually paler. In some the color is almost solid, in others transversely banded with darker and paler shades giving the larva a knotted or mottled appearance which is especially effective protection when at rest on the disk of a composite such as a sunflower. Their colors match perfectly with the varying shades of color of the maturing corn silks. The larvæ are so slender, especially in the early instars that they are not readily distinguished from the strands of silk and, except for the fact that they are so active, would be hard to find. When a lock of silk is disturbed the larvæ, especially the larger ones, which may happen to be on the outside and not entangled in the silk, drop instantly as if falling, but almost invariably suspend themselves by a strand of silk. Occasionally one falls free but generally lodges on a leaf below. They usually drop about three or four inches but sometimes as little as half an inch and in one instance a larva was observed to drop four feet and hang suspended only a few inches above the ground. After dropping they hang perfectly straight and motionless for a few seconds and then by a twisting, squirming motion of the head and thorax, using the thoracic legs to wind up the silk, draw themselves back to their former location. The larger larvæ are extremely nervous and will jump and throw themselves violently about at the least irritation. If a lock of silk be lifted and spread out a little and held quietly for a few seconds the younger larvæ and those entangled in the silk become active, holding fast by the abdominal legs and waving the anterior part of the body in the air or remaining in a humped position. This activity reveals their presence.

During periods of greatest abundance often every lock of silk not entirely dry is infested. As many as 13 larvæ have been found in a single lock and averages of four or five are common. The number of larvæ is often incommensurate with the great abundance of the moths, and cannabalism may account, in part, for this. Larvæ confined in boxes often cripple one another and in one instance a larva was found in the field in the act of consuming a smaller neighbor.

As long as the silk is fresh, larvæ move about from ear to ear to only a slight extent but toward the close of the season when the silks are dry they are frequently found on other parts of the plant searching for food. They have several times been found in the leaf axils feeding on the corn pollen accumulated there. When silk becomes scarce they often congregate on the few late ears and keep the silk cut off close to the tip of the shuck. In a cage confined to an ear with drying silk, they push down inside the tip of the shuck after green food but only to a very slight extent. It is rather unusual to find newly hatched larvæ or even eggs on silks less than three or four days old.

Apparently the only possible damage these larvæ can do is to cut off the silk before fertilization of the ovules has taken place and a few ears have been found where this apparently had occurred. Generally, however, pollination is accomplished so soon after the appearance of the silk that injury from this cause is unlikely.

The newly hatched larvæ eat first the minute succulent hairs on the silks. After a little they gnaw along the side of the strands and finally consume the entire strand. The tissue is so succulent that the larger larvæ can consume a surprising quantity of it in a day.

THE PUPA.

Description. Length 11 mm., width 2.2 mm. Head bent so strongly ventrad as scarcely to be visible from above. Mesothorax large and produced at each lateral angle into an acute, laterally flattened process extending cephalad .6 mm. the prothoracic area between these processes flattened and with eight black dots arranged roughly in a triangle. Meso- and metathorax flattened and only slightly convex above, gibbous ventrad. Mesothorax above finely rugose and with a shining narrow median carina, posterior margin angularly convex. Appendages and wing cases covering the venter of the thorax and extending nearly to the caudal margin of the fourth abdominal segment,

the costal margin of the wings extending slightly above the lateral line. Ten abdominal segments visible above, the fourth and fifth the longest; cremaster flattened and separated from the tenth segment by a sharp notch on each side, bearing at its tip four pairs of curled hooked spines, the two distal pairs stout, diverging from a single point and turned latero-ventrad, the other two pairs much smaller and arising from four minute dusky spots just cephalad of the tip above, and curling toward each other.

In color the pupa varies from pale green to deep reddish-brown, always paler beneath. The cephalic margin of the mesothorax is marked by a narrow dark line running out to the tip of the cephalic processes. A more or less dusky line runs caudad on each side from the base of these processes along the dorsal margin of the wing case and ends on a dusky spot about even with the third abdominal segment. There is a pair of small round dark dots on the dorsum of each segment except the prothorax and the ninth abdominal.

Pupation. When mature the larva seeks a sheltered place somewhere about the plant, sometimes within the lock of silk but more often on the shuck beneath or behind the silk, on the other side of the ear between it and the stalk, or under or within a leaf elsewhere on the plant. When pupating in the silk a very slight filmy white cocoon is sometimes formed but in other locations this is dispensed with. The larva spins a small pad of brownish-yellow silk within which the crochets of its caudal legs and later the spines of the cremaster remain entangled. It also forms a girdle of a single thread attached to the surface on each side and passing over its body between the third and fourth abdominal segments. Before pupation the mesothorax becomes greatly enlarged and the head and shrunken prothorax are bent sharply ventrad. The pupa with its two cephalic processes is very characteristic and can hardly be confused with that of any other species. The pupal period is short, from six to nine days, usually seven.

LIFE CYCLE.

No attempt was made to determine the duration of the separate larval instars. The duration of the entire larval life in summer is very short, from 12 to 18 days. Larvæ which completed their larval life in 12 days emerged as moths six days later. Three days more for the egg stage makes 21 days for the minimum complete life cycle, assuming that the moths deposit eggs soon after emergence. Allowing the average of three days for the egg, 14 days for the larval stage and seven for the pupal

stage we have a total of 24 days for a normal average life cycle in midsummer with food abundant. These figures check very well with the collection records of the moths where the crest of the waves of abundance came just three weeks apart. In the spring and fall with temperatures lower and food not so abundant or palatable, the life stages are undoubtedly of longer duration.

PARASITES.

The larvæ are freely parasitized but, in our experience, by only one species, *Apanteles nemoriæ* Ashm. This same parasite also attacks other small flower feeding geometers. (4, p. 543). Only one individual matures in a single host larva. The mature grubs leave the host through the side in the abdominal region, in one observed instance through the left side of the fifth abdominal segment. The host remains alive but motionless for several hours after the emergence of the parasite and finally dies. The *Apantales* cocoon is white, 3 mm. long and 1.2 mm. wide, surrounded with loose silk. The adult emerges five or six, usually five, days after the cocoon is formed. When adults of this parasite were allowed to attack healthy reared larvæ the grubs left their host eight or nine days later. This indicates a very short life cycle for the parasite, scarcely over two weeks. Although the cocoons of this parasite were quite abundant at times the parasitism never reached 10% of the larvæ collected in the field and reared. Neither did the degree of parasitism increase toward the close of the season.

In a few cases this parasite was attacked by a secondary, determined as *Mesochorus* sp., a slender, golden-yellow species. This hyperparasite evidently attacks its host while the latter is within the body of the caterpillar. The *Apanteles* grub emerges from its host and cocoons normally. Nine days later the *Mesochorus* emerges instead of the expected *Apanteles*.

OTHER ENEMIES.

As mentioned above the larvæ are somewhat cannabalistic. They are also eaten by larvæ of *Chauliognathus pennsylvanicus* DeG. and both larvæ and pupæ are readily eaten by larvæ of the corn ear worm, *Heliothis obsoleta* Fab. One larva was taken by Mr. Cartwright impaled on the rostrum of an adult *Podisus maculiventris* Say.

LITERATURE CITED.

(1) Britton, W. E.
1920. Checklist of the insects of Connecticut, Conn. St. Geol. & N. H. Surv., Bul. 31; 1-397.

(2) Dyar, H. G.
1902. List of North American Lepidoptera, U. S. N. M. Bul. 52; 1-723.

(3) Forbes, S. A.
1905. Monograph of insect injuries to Indian corn, *in* Rept. St. Ent. Ill., 23: 1-273.

(4) Muesebeck, C. F. W.
1920. Revision of the North American species of Ichneumon flies belonging to the genus *Apanteles*, *in* Proc. U. S. N. M., 58: 483-576. (Sep. 2349).

(5) Packard, A. S., Jr.
1876. Monograph of the Geometrid moths of the United States. Rept. U. S. Geol. Surv. Terr. 10: 1–607.

(6) Smith, J. B.
1893. Insects of the year in New Jersey, *in* Insect Life, 6: 187-192.

(7) Smith, J. B.
1910. Insects of New Jersey, p. 1-888.

(8) Walker, F.
1861. Catalog of the British Museum, 22:

This paper received for publication April 8, 1922.

SOME TINGITIDAE FROM JAPAN (HEMIP.)*

CARL J. DRAKE
Department of Zoology and Entomology, Iowa State College

Sometime ago the writer received, through the kindness of Mr. W. L. McAtee, a small collection of lace bugs or Tingitidæ from Japan. In addition to a few new records the collection contains a new genus and three new species. *Galeatus peckhami* Ashm. was wrongly recorded by Uhler from Japan; this insect seems to be limited in distribution to the northern portion of the Nearctic region. Although I have examined specimens of *Stephanitis pyrioides* Scott from Japan, the species listed by Uhler as this insect (*Tingis pyrioides* Scott) is *Tingis pyri* Fabr.

Monanthia formosa n. sp.

Moderately large, rather robust. Head short, with five appressed spines; posterior spines much longer than the anterior spines, the latter short. Antennæ rather slender, moderately long; first and second segments subequal in length, the former a little thicker and stronger; third segment very long and slender, almost three times the length of the fourth; fourth segment slightly swollen, clothed with several long hairs. Rostral laminæ widely separated on the metasternum, meeting behind. rostrum reaching to the intermediate coxæ. Pronotum narrowed anteriorly, considerably and transversely swollen through the disc; Paranota strongly developed, reflexed back against the pronotum, the outer margins contiguous with the median carina, with prominent nervures, the nervure next to the outer margin strongly costate. Median carina distinctly raised, rather thin, with a row of small areolæ. Lateral carinæ short, not very prominent, divaricating posteriorly. Elytra moderately constricted a little beyond the middle, considerably longer than the abdomen, broadly rounded at the apex; tumid elevation moderately large; costal area uniseriate throughout, the areolæ rather large; subcostal area triseriate, the areolæ considerably smaller than those of discoidal area; discoidal area extending to the middle of the elytra, slightly unequally reticulated, narrow at the base and broadly rounded at the apex, the outer nervure at the base strongly, roundly and outwardly curved; sutural area rather widely and somewhat unequally reticulated. Wings a little shorter than the elytra. Length, 2.6 mm.; width about 1 mm.

---

* Contributions from Department of Zoology and Entomology, Iowa, State College, Ames, Iowa.

Legs and antennæ light testaceous. Body beneath black. Head black, the spine whitish. Paranota whitish, a few of the nervures fuscous. Nervures of apex of pronotum and of the elytra mostly fuscous (few testaceous), the areolæ largely whitish and nearly opaque. Most of the areolæ of sutural area broadly margined with fuscous.

Fifteen specimens, Kankau (Koshun), Formosa, Japan, 1912, collected by Mr. H. Sauter. *Type*, male, in the collection of Dr. Walter Horn, Berlin, Germany. *Paratypes* in the collections of U. S. National Museum, Dr. Horn and writer. In some specimens the fourth antennal segment is slightly embrowned. The smaller size, the lighter color of legs and antennæ, and size of paranota separate this species at once from the new form described below.

Monanthia sauteri n. sp.

Very closely allied to *M. formosa* n. sp., but readily separated from it by the stouter and more robust form, much narrower paranota (not contiguous with the median carina), nearly parallel lateral carinæ, and the lighter color of the reticulations of the elytra and paranota. Length, 2.82 mm.; width, 1.3 mm.

Pronotum transversely swollen through the disc, coarsely punctate; median carina well-developed, composed of a single row of small areolæ; lateral carinæ short, each composed of two small areolæ; paranota with two or three rows of punctures between its outer margin and the median carina. Elytra similar to *M. formosa* n. sp.; discoidal area not quite reaching the middle of the elytra; subcostal area mostly triseriate, with a few extra areolæ at its widest part (back of apex of discoidal area). Wings almost as long as elytra.

Antennæ testaceous, the fourth segment mostly fuscous. Legs testaceous, the tarsi fuscous. Head black, the spines testaceous. Pronotum and body beneath black; reticulations of paranota testaceous, the areolæ whitish. Reticulations of elytra mostly brown, the cells whitish.

Type, female, Kankau (Kushun), Formosa, Japan, May, 1912, collected by Dr. H. Sauter, in the collection of Doctor Walter Horn. *Paratype*, Tainan, Formosa, Japan, 1912, collected by H. Sauter, in my collection. In the latter specimens the nervures of the elytra are dark fuscous.

Belenus dentatus Fieber.

Phyllontochila dentata Fieber, Ent. Monog., 1844, p. 71, Pl. VI, Figs. 2–4.
Phyllontochila dentata Stal, Enum. Hemip., III, 1873, p. 126.
Belenus dentatus Distant, Ann. Soc. Ent. Belg, LIII, 1909, p. 116, (*type* of genus).

Several specimens, taken at Anping and Taihorin, Formosa, 1911, by Mr. H. Sauter.

Stephanitis pyri Fabricius.

Acanthia pyri Fabricius, Syst. Ent., 1775, p. 696.
Cimex appendiceus Geoffroy, Ent., Paris, 1785, p. 212.
Tingis pyri Syst. Rhyng., 1803, p. 126.
Tingis marginata Lamarch, Hist. Nat., III, 1816, p. 504.
Stephanitis pyri Horvath, Ann. Mus. Hung., IV, 1906, p. 54; Ann. Mus. Hung. X, 1912, pp. 320, 327.

This species was recorded by Uhler as *Tingis pyrioides* Scott from Japan. Numerous specimens of the true *S. pyri* Fabr. are before me from Japan, also one specimen from China.

Stephanitis pyrioides Scott.

Stephanitis pyrioides Scott, Ann. Mag. Nat. Hist., Ser. 4, XIV, 1874, p. 440.
Stephanitis azalaea Horvath, Ann. Nat. Mus. Hung., IV, 1906, pp. 55, 56; Ann. Nat. Hist. Hung., X, 1912, pp. 323, 333.

Several specimens of the true *S. pyrioides* Scott have been examined by the writer from Japan.

Stephanitis globulifera Matsumura.

Tingis globulifera Matsumura, Senchu-Zukai, II, 1905, p. 36, Pl. 19, Fig. 16.
Stephanitis globulifera Horvath, Ann. Mus. Nat. Hung. X, 1912, pp. 322, 330.

Specimens of this insect were taken in Japan by Mr. Koebele.

Stephanitis typica Distant.

Cadamustus typicus Distant, Ann. Soc. Ent. Begl., XLVII, 1903, p. 47; Fauna Brit. Ind., Rhynch., II, 1903, p. 132, Fig. 95.
Stephanitis typica Horvath, Ann. Nat. Hist., Hung., X, 1912, pp. 320, 325.

A long series, taken at Hoozan, Formosa, during 1908, 1909, 1911 and 1912, by Mr. H. Sauter.

Galeatus spinifrons Fallen.

Tingis spinifrons Fallen, Mon. Cim. Svec., 1807, p. 38.
Tingis affinis Herrich-Schaeffer, Nom. Ent., 1, 1835, Wanz. Ins., III, p. 73, Pl. 95, Fig. 290.
Galeatus spinifrons Jakowleff, Bull. Soc. Mosc., I, 1880, p. 131; Horvath, Termes, Fuzetk., XX, 1897, p. 456.

This insect was listed by Uhler in "Summary of the Hemiptera of Japan, presented to the United States National Museum by Professor Mitzukuri," Proc. U. S. Nat. Mus., Vol. XIX, No. 1108, 1896, p. 265, as *Galeatus peckhami* Ashmead. The comment, "I can find no structural differences to separate these (four specimens from Japan) from the vertible type as it occurs in lower Canada" refers to the true *G. peckhami* of Ashmead. Horvath has recently described the form listed by Uhler, Proc. U. S. Nat. Mus., XXVII, 1904, p. 362, as a new species. According to specimens at hand *G. peckhami* Ashm. is entirely of Nearctic distribution and ranges from Wisconsin and Muskoka Lake, Canada, to the Atlantic. (*Fide* Bergroth).

Xenotingis n. gen.

Distinctly lacely like the genera Stephanitis, Cadmius, Leptodictya and Galeatus but distinguished at once from those or other allied genera by enormously developed paranota and the strongly recurved outer margin of each elytron. Pronotum tricarinate. Head mostly concealed by the hood, with five slender, rather short spines; hood narrow, extending to the apex of the head. Eyes small. Bucculæ meeting in front. Paranota enormously developed, strongly reflexed and recurved, the rostrum long and slender, the rostral groove uninterrupted. Elytra considerably longer than the abdomen, rounded at the apex; discoidal area broad, not quite reaching the middle of the elytra; costal area broad, the outer margin strongly recurved (rolled) and touching the discoidal and subcostal areas. Elytra and paranota widely reticulated. Metasternal orifice quite distinct.

Type of genus *Xenotingis horni* n. sp.

Xenotingis horni n. sp. (Fig. 1).

Pronotum distinctly punctate, transversely swollen through the disc, tricarinate; lateral carinæ thin, parallel, without areolæ; median carina more strongly raised than the lateral carinæ, especially behind. Hood narrow, projecting a little in front of the head, a little longer than high, widely reticulated. Paranota enormously developed, strongly recurved, projecting high above the pronotum, nearly semiglobose in shape, the areolæ very large and finely reticulated. Head rather short, the spines appressed. Rostrum reaching almost to the third ventral segment of the abdomen. Antenniferous tubercles moderately large. Antennæ rather long and slender; first segment a little longer and thicker than the second; third segment very long, slender, slightly curved, more than four times the length of the fourth. Elytra broadly rounded at the apex, considerably longer than the

abdomen, widely reticulated, the outer margin recurved; discoidal area broad, not reaching the middle of the elytra, with five rows of areolæ at its widest part; sutural area large, widely reticulated; costal area irregularly quadriseriate. Wings wanting. Length, 3.6 mm.; width, 1.58 mm.

General color above uniformly testaceous, the areolæ semi-transparent. Body, legs and antennæ a little darker, somewhat more brownish, the tarsi and fourth antennal segments fuscous.

Type, female, from Kosempo, Formosa, Japan, August, 1909, collected by H. Sauter, in the collection of Dr. Horn.

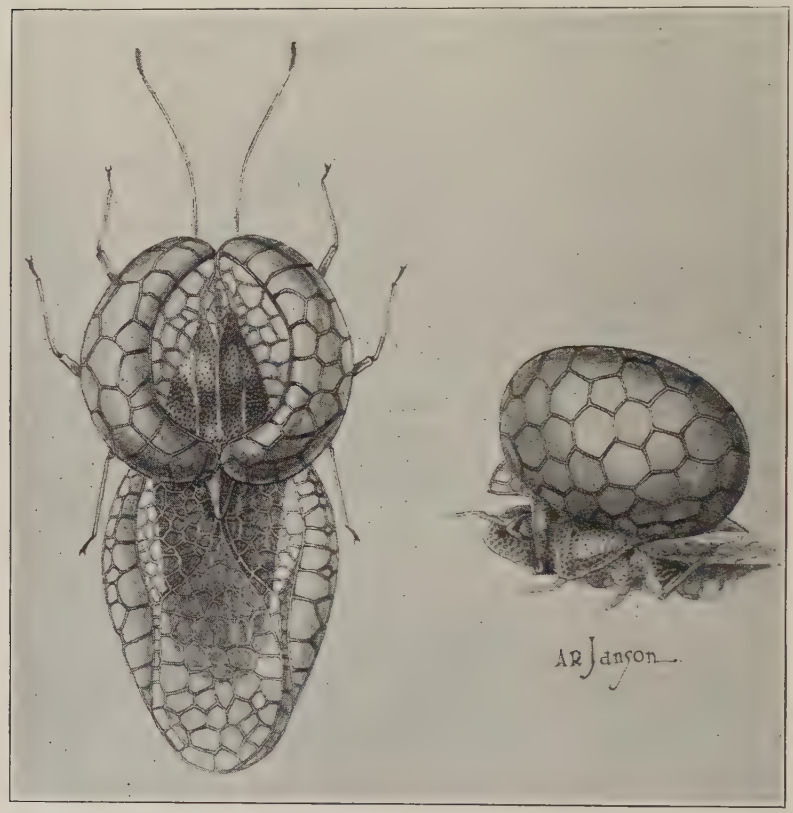

Fig. 1. *Xenotingis horni* n. gen. and sp.

This paper received for publication January 12, 1923.

ADDITIONS TO THE CATALOG OF OHIO VASCULAR PLANTS FOR 1922.*

JOHN H. SCHAFFNER
Department of Botany, Ohio State University

Although the flora of Ohio is perhaps as well known as that of any of the States, except a few on the Atlantic border where botany has been studied longer and more intensively, there yet remains much to be done, both in determining the range of the species and the actual species present within our borders.

Below is a list of the more important additions contributed by various individuals. It is hoped that all interested in Ohio plants and in plant geography in general will continue to send specimens to the herbarium.

17. *Pteridium aquilinum* (L.) Kuhn. Change name to *Pteris aquilina* L. Eagle-fern.

44. *Matteuccia struthiopteris* (L.) Todaro. Change name to *Pteretis nodulosa* (Mx.) Nieuwl. American Ostrich-fern. Our species is distinct from the European *Pteretis struthiopteris* (L.) Nieuwl.

Below is a corrected list of the Ohio species of Equisetum.

50. *Equisetum hiemale*. L. Omit from the list. This species is not known to occur east of the Rocky Mountains.

51. *Equisetum præaltum* Raf. Great Scouring-rush. General in the state and often abundant.

52. *Equisetum variegatum* Schleich. Variegated Scouring-rush. Ashtabula County.

52a. *Equisetum variegatum jesupi* A. A. Eat. (Probably *E. variegatum* X *E. præaltum*). Lake County.

53. *Equisetum lævigatum* A. Br. Smooth Scouring-rush. General but apparently not common.

53.1. *Equisetum kansanum* Schaffn. Kansas Scouring-rush. Wood, Erie, Lorain, Summit, Stark, Monroe.

53.2. *Equisetum palustre* L. Marsh Horsetail. Portage County

---

* Papers from the Department of Botany, Ohio State University. No. 139.

54. *Equisetum fluviatile* L. Water Horsetail. Not common but to be found in most parts of the state in suitable places.
55. *Equisetum silvaticum* L. Wood Horsetail. Cuyahoga, Geauga.
56. *Equisetum pratense* Ehrh. Omit from the list. Not known to occur in Ohio. If present, to be found in the extreme north-eastern section.
57. *Equisetum arvense* L. Field Horsetail. General and abundant.

The species should be arranged in the following order to be in the proper phyletic sequence: 53, 51, 52, 52a, 53.1, 54, 53.2, 55, 57.

---

65. *Selaginella apus* (L.) Spring. Creeping Selaginella. At base of wet limestone cliff, Rocky Fork Creek, Highland Co. Caves, Highland Co. Mrs. Bayard Taylor.
71. *Pinus echinata* Mill. Short-leaf Yellow Pine. Colerain Twp., Northeastern Ross Co. "Sparsely distributed; confined to the sandstone hills of Harrison and Colerain Twps. in this county." Also in Springfield Twp., Gallia Co., and generally distributed in Green, Greenfield, Ohio, and Raccoon Twps. F. W. Dean. Correct the following mistake in note on distribution in 1921 "Additions." Read Northwestern Jackson County instead of Northeastern Jackson County.
72. *Thuja occidentalis* L. Arborvitæ. Reported to occur in a few isolated places along Brush Creek in Green Twp. and in the Gorge at Cedar Falls; in Jefferson Twp., Adams Co., by F. W. Dean.
108. *Brasenia schreberi* Gmel. Water-shield. Jackson Twp., Franklin Co., John H. Schaffner.
109. *Nelumbo lutea* (Willd.) Pers. American Water-lotus. Jackson Twp., Franklin Co. Robert B. Gordon.
133. *Wolffia columbiana* Karst. Columbia Wolffia. Jackson Twp., Franklin Co. Probably quite generally distributed in the state; our smallest flowering plant. John H. Schaffner.

216.1. *Carex suberecta* (Olney) Britt. Prairie Straw Sedge. Big Darby Creek, Franklin Co. Edward S. Thomas.

331. *Poa brachyphylla* Schult. Change name to *Poa Cuspidata* Nutt. Cuspidate Spear-grass. Specimens collected two miles north of Steece, Lawrence County, by Chas. C. Deam, of Bluffton, Ind. Determined by Agnes Chase, of the U. S. National Herb. Specimens in Deam herbarium. Also in Ohio State Univeristy herbarium, specimens from Lawrence, Trumbull, Cuyahoga, Perry, Medina and Ottawa Counties.

366. *Secale cereale* L. Rye. "Persistent after cultivation and escaped to waste places." Hillsboro, Highland County. Katie M. Roads.

448. *Panicum boscii* Poir. Bosc's Panic-grass. Big Darby Creek, Franklin County. Edward S. Thomas.

465. *Holcus halapensis* L. Johnson-grass. Near Hillsboro, Highland County. "According to farmers, it is crowding out alfalfa in alfalfa fields." C. J. Willard. Also "Rather abundant in a pasture field," Berrysville, Highland County, Katie M. Roads.

483. *Allium vineale* L. Field Garlic. In a waste field, Columbus, Franklin County. John H. Schaffner.

488. *Ornithogalum umbellatum* L. Star-of-Bethlehem. Along a road in moist meadow. Bloom Twp., Fairfield County. John H. Schaffner. Also "very common in fields and waste places." Hillsboro, Highland County. Katie M. Roads.

528. *Pontederia cordata* L. Pickerel-weed. Jackson Twp., Franklin County. John H. Schaffner and Robert B. Gordon.

532. *Tradescantia pilosa* Lehm. Zigzag Spiderwort. "In yards and waste places," Hillsboro, Highland County. Katie M. Roads.

558. *Iris cristata* Ait. Crested Dwarf Iris. "Covered a hillside." Hillsboro, Highland County. Katie M. Roads.

604. *Magnolia tripetala* L. Umbrella Magnolia. About 6 miles N. W. of Jackson, Jackson County, headwaters of Pigeon Creek, Liberty Twp. "In bottom lands and lower slopes of deep ravines. The species is abundant with numerous fine specimens 35–40 ft. high and 4–5 in. in diameter." "Also in extreme upper

edge of Eagle Township, Vinton County, nearly on the county line between Vinton and Hocking Counties, 4 miles north of Eagle Mills, along ravine near main stream of Salt Creek." F. W. Dean.

623. *Batrachium circinatum* (Sibth.) Rchb. Circinate White Water-crowfoot. Jackson Twp., Franklin County. John H. Schaffner.

629. *Aquilegia vulgaris* L. European Columbine. "Occasional in waste ground." Hillsboro, Highland County. Katie M. Roads.

641. *Viorna viorna* (L) Small. Leather-flower. Lucas Co., J. W. Hawkins; Coshocton Co., Everett Lowary. Reported by F. Detmers.

680. *Fumaria officinalis* L. Common Fumitory. "On the bank of a small pond." Hillsboro, Highland County. Katie M. Roads.

703. *Thlaspi arvense* L. Field Penny-cress. Union Twp., Highland County. Katie M. Roads.

712. *Norta altissima* (L.) Britt. Tall Hedge-mustard. "Introduced weed in pasture fields and lots." Hillsboro, Highland County, Katie M. Roads. Also Columbus, Franklin County, Robert B. Gordon.

715. *Hesperis matronalis* L. Dame's Rocket. "Occasional in woods and waste ground, Hillsboro, Highland County. Katie M. Roads.

718. *Barbarea stricta* Andrz. Erect Winter-cress. "Not common." Hillsboro, Highland County. Katie M. Roads.

719. *Barbarea verna* (Mill.) Aschers. Early Winter-cress. "Very abundant in grainfields and pasture land." Hillsboro, Highland County. Katie M. Roads.

747. *Brassica campestris* L. Common Turnip. "In a pasture lot." Hillsboro, Highland County. Katie M. Roads.

775. *Linum virginianum* L. Virginia Flax. "Dry woods." Washington Twp., Highland County. Katie M. Roads.

786. *Brassica juncea* (L.) Cosson. Indian Mustard. "In waste places." Union Twp., Highland County. Katie M. Roads.

796. *Mercurialis annua* L. Mercury. Columbus, Franklin County. John H. Schaffner.

803.1. *Tithymalus darlingtonii* (Gr.) Small. Darlington's Spurge. "Moist hillside." Hillsboro, Highland County. Katie M. Roads.

814. *Callitriche austini* Engelm. Terrestrial Water-starwort. Jackson Twp., Franklin County. In a moist pasture near pond. One of our smallest flowering plants. John H. Schaffner and Robert B. Gordon.

927. *Dianthus barbatus* L. Sweet-William. "Escaped from cultivation." Hillsboro, Highland County. Katie M. Roads. Also in waste pasture-land, north of Columbus, Franklin County, John H. Schaffner.

932. *Portulaca grandiflora* Hook. Garden Portulaca. Escaped. "In waste places," Hillsboro, Highland County. Katie M. Roads.

976. *Pleuropteris zuccarinii* Small. Japanese Knotweed. Zanesville, Muskingum County, F. M. Reed; Hillsboro, Highland County, Charles Johnston. Reported by F. Detmers.

1008. *Potentilla argentea* L. Silvery Cinquefoil. "Dry pasture land." North of Columbus, Franklin County. Robert B. Gordon.

1009. *Potentilla recta* L. Upright Cinquefoil. "Rather common in pasture lots." Hillsboro, Highland County. Katie M. Roads.

1022.1. *Rubus laciniatus* Willd. Cutleaf Blackberry. "A large patch in a pasture lot." Hillsboro, Highland County. "In several other places in the county." Katie M. Roads.

1082. *Cratægus phænopyrum* (L. f.). Medic. Washington Hawthorn. Dayton, Montgomery County. Wm. B. Werthner.

1160.1. *Lespedeza striata* (Thunb.) H. and A. Japan Bush-clover. Reported as escaped in pastures, South Bloomingville, Hocking County. Homer C. Sampson. Probably quite common in the southern part of the state. From eastern Asia.

1269. *Quercus stellata* Wang. Post Oak. Jackson Twp., Franklin County. Rare locally. John H. Schaffner and Robert B. Gordon.

1271a. *Quercus imbricaria* x *velutina*. Lea's Oak. Dayton, Montgomery County. William B. Werthner.

1272. *Quercus marilandica* Muench. Black-Jack (Oak). Springfield Twp., Gallia County. "On poor clay ridge—in mixture with post and quercitron oaks and short-leaf pine." F. W. Dean.

1329. *Ribes odoratum* Wendl. Buffalo Currant. "Very common along fences and waste places." Hillsboro, Highland County. Katie M. Roads.

1380. *Anagalis arvensis* L. Scarlet Pimpernel. Jackson Twp., Franklin County. John H. Schaffner and Robert B. Gordon.

1400. *Andromeda polifolia* L. Wild Rosemary. Cranberry bog, Buckeye Lake, Licking County. Planted in the bog. F. Detmers.

1432. *Convolvulus spithamæus* L. Upright Bindweed. Dry rocky soil, near Girl's Industrial School, Delaware County. John H. Schaffner.

1455. *Chionanthus virginica* L. Fringe-tree. Along Aaron Creek, two miles west of Arabia, Aid Twp., Lawrence County. "Growing in open field surrounded by old field type of Sassafras, sumac, persimmon, etc. Upper southwest slope." F. W. Dean.

1502. *Physalodes physalodes* (L.) Britt. Apple-of-Peru. "In a cultivated field." Hillsboro, Highland County. Katie M. Roads.

1537.1. *Veronica glandifera* Pennel. Glandular Speedwell. Reported for Ohio by F. W. Pennel; no specimens in the state herbarium. Collected at Oxford, Butler County, by Bruce Fink.

1540. *Veronica teucrium* L. Change name to *Veronica latifolia* L. Broad leaf Speedwell, of which it is a synonym.

1554. *Aureolaria lævigata* (Raf.) Raf. Entire-leaf False Foxglove. Dean Forest, Lawrence County. Reported by F. Detmers.

1580. *Martynia louisiana* Mill. Unicorn-plant. Alliance, Stark County, S. E. Nold; Marion, Marion County, M. C. Thomas; Uhrichsville, Tuscarawas County, W. L. Wilcoxon; Barberton, Summit County, L. S. Swigart. Reported by F. Detmers.

1605.1. *Borago officinalis* L. Borage. "Introduced in package of herb seed, from Chicago Seed House." In garden, Wooster, Wayne County. In herbarium of State Agr. Exp. Sta., Wooster. Reported by F. Detmers.

1610. *Verbena angustifolia* Mx. Narrow-leaf Vervain. "Very common in pastures." Hillsboro, Highland County, Katie M. Roads.

1612. *Lamium purpureum* L. Red Henbit. Hillsboro, Highland County. Katie M. Roads.

1661. *Perilla frutescens* (L.) Britt. Perilla. "An escape everywhere" around Hillsboro, Highland County. Katie M. Roads.

1696. *Plantago virginica* L. Dwarf Plantain. "Very common in pastures." Hillsboro, Highland County. Katie M. Roads.

1864. *Bidens laevis* (L.) B. S. P. Smooth Bur-marigold. Hillsboro, Highland County. Katie M. Roads.

1875a. *Galinsoga parviflora hispida* DC. Hairy Galinsoga. "A common weed in gardens and waste places." Hillsboro, Highland County. Katie M. Roads.

1882.1. *Chrysogonum virginianum* L. Chrysogonum. Waterford, Washington County, and Peninsula, Summit county. In herbarium of State Agr. Exp. Sta., Wooster. Reported by F. Detmers.

1888. *Boebera papposa* (Vent.) Rydb. Fetid Marigold. "Very abundant in a pasture." Hillsboro, Highland County. Katie M. Roads.

1889. *Inula helenium* L. Elecampane. "Rare along fence rows." Hillsboro, Highland County. Katie M. Roads.

1903. *Chrysopsis mariana* (L.) Nutt. Maryland Golden-aster. Dean Forest, Lawrence County. Reported by F. Detmers.

1988. *Elephantopus carolinianus* Willd. Carolina Elephant's-foot. Gallipolis, Gallia Co., C. A. Smith. In herbarium of State Agr. Exp. Sta., Wooster. Reported by F. Detmers.

2023.1. *Cirsium hillii* (Canby) Fernald. Hill's Thistle. In fields, Lisbon, Columbiana County. G. W. Armstrong. In herbarium of State Agr. Exp. Sta., Wooster. Reported by F. Detmers.

2026a. *Cirsium arvense integrifolium* Wimm. & Grab. "The smooth variety of Canada thistle, recognized by Gray, seems to be quite common for it has quite frequently been sent in to the Experiment Station. Differs from the typical Canada thistle not only in leaf characters but lacks the horizontal rhizome. Edison, Morrow County. W. J. Campbell; North Olmstead, Cuyahoga County, D. K. Huntington; Piqua, Miami County, Fred DeWees. These three counties indicate the scattered distribution of this interesting variety or form of the dreaded Canada thistle. Interesting because it is much more easily eradicated than the type." In herbarium of State Agr. Exp. Sta., Wooster. Reported by F. Demters.

2030.1. *Centauria solstitialis* L. Barnaby's Star-thistle. "Frequent in alfalfa fields." Van Wert, Van Wert County; Wauseon, Fulton County., R. A. Cave. Reported by F. Detmers.

2035. *Hypochaeris radicata* L. Long-rooted Cat's-ear. On lawn, Wooster, Wayne County. F. Detmers.

2035.1. *Picris echinoides* L. Bugloss Picris. Wheat field, Carrollton, Carroll County. Charles E. Capper. In herbarium of State Agr. Exp. Sta., Wooster. Reported by F. Detmers.

This paper received for publication January 12, 1923.

Edmund McCullin